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A Reference Handbook
OF
THE MEDICAL SCIENCES

EMBRACING THE ENTIRE RANGE OF

SCIENTIFIC AND PRACTICAL MEDICINE
AND
ALLIED SCIENCE

BY VARIOUS WRITERS

A NEW EDITION, COMPLETELY REVISED AND REWRITTEN

EDITED BY ALBERT H. BUCK, M.D.
NEW YORK CITY

VOLUME IV.

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A REFERENCE HANDBOOK

OF

THE MEDICAL SCIENCES.

ERGOT (*Ergota*, U. S. P., Br. P.; *Secale cornutum*, Ph. G.; *Ergot de Seigle*, Codex Med.), *Fungus Secalis; Mutterkorn;* Spurred Rye, etc., consists of the sclerotium of *Claviceps purpurea* (Fries) Tulasne, Order *Ascomycetes*, replacing the grains of rye, *Secale cereale* Linn. Our Pharmacopœia prescribes that ergot should be only moderately dried, preserved in a closed vessel, chloroformed occasionally to prevent the development of insects, and rejected as unfit for use when more than a year old. This remarkable parasite is developed in the flowers of several cultivated grains and of a considerable number of wild grasses, germinating upon the ovaries, which it aborts and finally destroys, and growing in the place of these organs like some monstrosity of the flowers themselves. It attains to a sort of maturity as the grain ripens in the fall, and in this condition remains quiescent until the following season, when, if in a suitable situation, as upon the surface of damp ground, it produces spores in time to attack the blossoming grasses and grains of the succeeding year. It is this resting-stage which constitutes the "sclerotium."

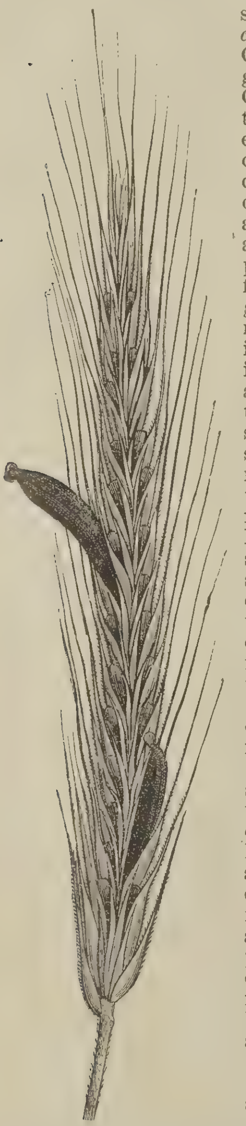

FIG. 1940.—Ear of Rye with two Ergots. Natural size. (From Luerssen.)

The first noticeable evidence of the presence of this fungus in a spikelet, say of rye or wheat, is a sticky, unpleasant-smelling, very sweet, liquid exudation from the interior of one of the flowers, which accumulates in considerable quantity, and may even drop off or run down the stem. It consists mostly of some sort of sugar, and is probably a decomposition product of the affected pistil, etc. Like similar results of the irritation of vegetable tissues by other fungi, as well as by aphides, etc., it is known as "honey dew," and designated the "honey dew of rye." It is a certain sign that ergot will follow. Ants and beetles are fond of it, flock to the ears where it is to be found, and as it contains cells capable of developing into ergot in other flowers, they assist in spreading the blight. Bees are said to avoid it. A soft, spongy or cottony, mould-like tissue, consisting of long, fine, weak filiform cells, felted together at this time, envelops and permeates the ovary; as it grows the latter becomes disorganized and disappears, and the *mycelium* of the ergot, as this structure is called, takes its place. In a short time after, a very redundant and much wrinkled layer of perpendicular cells covers the surface of the mycelium, and produces an innumerable number of minute oblong false spores (*conidia*), which are discharged into the adhesive "honey dew" just mentioned. These are capable of reproducing the plant, and are the first method of propagation. In this stage it was at one time considered to be an adult and perfect plant, and named *Sphacelia segetum* (Léveillé, 1827) (see Fig. 1941). A further development next takes place in the formation and growth of the *sclerotium.* This begins as a condensation of tissue at the base of the "sphacelium" just described, the cells of which become shorter and thicker-walled, as well as more closely packed together. The mass becomes firm and brittle as it develops, the outer surface assumes a purple-black color, and it finally grows to a long spur-like, curved, irregularly cylindrical body protruding half its length or more beyond the plumes and paleæ of the rye. The "sphacelium" atrophies as the sclerotium grows, and is carried up on the apex, as

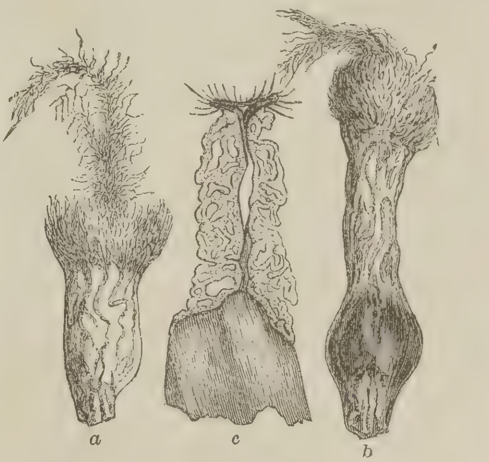

FIG. 1941.—*a*, Ovary of Rye with Commencing Growth of Claviceps in the Sphacelia Stage; *b*, the same with the parasite further developed; the hairy styles and the remains of the ovary are borne at the top of the mycelium, the commencing sclerotium or ergot is shown at the base; *c*, section of specimen a little older than *b*, and rather more magnified; the two styles and aborted ovary are seen at the top, the ruminated sphacelia in the middle portion, and the compact smooth ergot below. (Luerssen.)

are also any remains of the unfortunate pistil (see Fig. 1941). When the ergot is fully grown and gathered, scarcely any traces of either of these are to be found. At this stage ergot was also considered a distinct plant from the above, and it received separate names (*Sclerotium clavus* De Candolle, 1816, etc.). The growth of the first season terminates with the *sclerotium*, but in the early summer of the next year several minute globular heads raised upon stalks, half an inch or more in length, and looking like miniature "toadstools," grow from the sides of this organ and bear, in numerous cavities (*perithecia*), a multitude of groups of long and slender spores (see Figs. 1942 and 1943). These spores, applied to the flowers of suitable grasses, are capable of reproducing the whole series of forms described above, and complete the life history of the fungus. It is interesting to note that this stage of claviceps was also known long before its connection with the others was made out, and it was described and named by several authors (*e.g.*, *Sphæria*, *Cordiceps*, etc.).

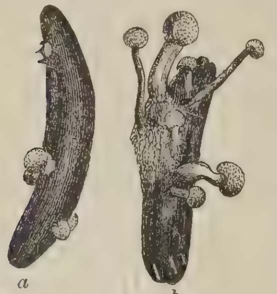

FIG. 1942.—Ergot in its Final Fructifying Stage. (Luerssen.)

The first botanist to follow the course of this plant through all its changes was M. Tulasne, who gave it its present name, and finally published his report upon it in the *Annales des Sciences Naturelles* for 1853. His investigations were so thorough, and his illustrations so fine, that but little has been added to either, so far at least as the botany of ergot is concerned.

HABITAT.—*Claviceps purpurea* is found in most temperate countries where the grains and grasses upon which it flourishes grow. It is, however, much less abundant in this country than in Europe, and there it occurs most generally in the warmer and moister countries. It is gathered in Central Europe, and especially in Spain and Central and Southern Russia. It is an incidental product of agriculture, and is sorted out from the grain at the harvest with the double purpose of collecting the ergot and of removing its baneful influence from the grain. Ergot of wheat is occasionally saved; it is shorter and thicker than that of rye, and medicinally equally good.

HISTORY.—Ergot has long been known as a blight upon grain and as a poison, but its medicinal history is comparatively modern. It appears to have been used by the peasantry, in some parts of Europe, in childbirth as much as three hundred years ago, and is mentioned by several authors of the sixteenth and seventeenth centuries in this connection; but its formal introduction into modern medicine is due to the efforts of Dr. Stearns, of New York, in the early part of the last century.

DESCRIPTION. — The above - described "*sclerotiums*," which constitute ergot, are from 1.5 to 3 cm. (½ to a little more than 1 in.) long and 3 mm. (1/8 in.) thick, oblong, tapering toward, but obtuse at both ends, triangular-cylindraceous, the sides unequally grooved; externally purple-black, nearly smooth; internally whitish, with purplish tinge or striæ, the fracture short, not sharp nor snapping; odor peculiar, disagreeable, especially upon trituration with potassium or sodium hydrate T. S.; taste oily and disagreeable. It moulds and spoils rather easily, and should be kept fresh and dry. It should not be broken or ground until needed for use. Microscopically it consists of closely entwined, elongated, thick-walled cells containing an abundance of oil drops. Of the commercial varieties, Russian and Spanish ergots are commonly preferred. Small or medium-sized grains are believed to be superior to very large ones.

COMPOSITION.—Ergot has been repeatedly examined within the past half-century, with the result of exhibiting a more and more complex composition with each successive investigation; but its active principle, if indeed there be any one substance entitled to the name, is still in doubt. One of its most abundant constituents is a *fat*, of which it contains from one-fourth to nearly one-third of its weight. This is a thick, bland, non-drying, light yellow oil consisting chiefly of olein with some palmitin and traces of glycerides of several common volatile, fatty acids. It has no therapeutic value, but is reported to be not without disagreeable action. It is recommended by Hager (as it is obtained in considerable quantity as a by-product of ergot preparations) for soaps and as a lubricant. A little *cholesterin* and *resin*, some *mycose* (sugar), several common *acids*, a fragrant *camphoraceous substance*, etc., are ingredients of no medicinal importance. In regard to the more active substances, scarcely any two chemists are agreed. *Ergotin* is a name given to various products, none of which is chemically pure. First, Bonjean's "ergotin" is prepared by treating a watery extract of ergot with alcohol, and evaporating the alcoholic solution to the consistence of a soft extract. It is a deep brown, strong-smelling, bitter substance, soluble in water and alcohol, of considerable activity and of frequent employment, but not an active principle properly so called. Wigger's ergotin was obtained by exhausting the ergot of wax, fat, etc., by means of ether, and then extracting with alcohol, evaporating the tincture, and washing with water. It is a sharp, bitter, reddish-brown powder, insoluble in water. Wenzell's *ergotine* (1864) was obtained by a more complicated process, and comes nearer the rank of a chemical compound. It is a brown, amorphous, bitter, alkaline substance, soluble in alcohol and water, but not in ether, and uniting with acids to form amorphous salts. Wenzell also separated another alkaloid, which he named *ecboline*, resembling his ergotine in most respects; on the other hand, other chemists assert that both of Wenzell's two alkaloids are practically the same, and that neither is pure. Tanret has isolated a crystalline alkaloid, which he has named *ergotinine*, soluble in ether, alcohol, and chloroform, but not in water. Its solutions rapidly decompose, and its value is not yet proved. A still more recent and very thorough analysis of ergot was made a few years ago in the laboratory of Dragendorff, with the result of separating the following, more or less well-defined, amorphous substances: 1. *Sclerotic acid*, a (yellowish-brown) hygroscopic, faintly acid, tasteless powder, obtained to the extent of from two to four per cent. 2. *Scleromucin*, a nearly related substance, two or three per cent. 3. *Sclererythrin*. 4. *Sclerojodin*, a coloring matter. 5. *Scleroanthin*. 6. *Sclerocrystalline*, etc. Sclerotic acid is an article of commerce, but not much called for. The others, excepting Bonjean's ergotin, are scarcely known excepting to the chemists who have isolated them.

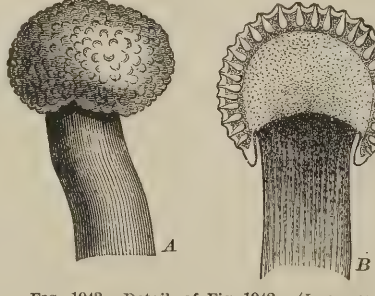

FIG. 1943.—Details of Fig. 1942. (Luerssen.)

Ergotic acid is a doubtful substance. *Ergotinic acid*, *sphacelinic acid*, and *cornutine*, described by Kobert, although none of them pure chemical compounds, are thought by Cushny most perfectly to represent the three distinct actions of the drug. Sphacelotoxin is regarded by Jacoby as the active constituent of sphacelinic acid, though this again appears resolvable into constituents, of which the most important one is called chrysotoxin.

From the foregoing it will be readily seen that ergot is not amenable to chemical assay for the determination of its quality, although, because of the highly varying action of different commercial samples, to some extent in kind as well as in degree, there are few drugs more in need of it. Under these circumstances, Houghton's method of physiological assay becomes of great interest. This consists in feeding the drug to fowls, then noting the extent and promptness of the discoloration of the comb, and finally rejecting any ergot which does not produce an effect reaching to a fixed standard. To this method various *a priori* objections have been urged by those who have not resorted to the very simple expedient of ascertaining the practical results of the method, which appear to have been the putting of an end to complaints of irregular or uncertain action.

Action.—The action of ergot and of its constituents is extremely complicated and can as yet by no means be said to be understood, though great progress has recently been made. We have now a fair knowledge of its practical effects as a drug. Our lack of knowledge relates mainly to the different effects produced by the different constituents, with the resulting disadvantage that we are unable intelligently to administer different preparations to meet special cases. The two most important effects of the drug are the prolonged contraction of the arteries, and the physiological strengthening of the natural rhythmic contractions of the uterus. Both of these effects are of complex origin, but primarily and principally due to the chrysotoxin or sphacelotoxin. In the production of the former effect, the chrysotoxin acts chiefly by stimulating the vaso-motor centre, to a lesser extent by acting directly upon the artery. At the same time, the vaso-motor centre is stimulated by the cornutine, but this stimulation is spasmodic and irritable, and is succeeded by depression, which, when the entire drug is used, may be supposed to act against the chrysotoxin, as there is often an early fall of blood pressure. This antagonism is still farther induced by the ergotinic acid, which is a direct depressor of the vaso-motor centre and of the heart, if introduced directly into the circulation. To get the full arterial effect, therefore, preparations of ergot should be given by the mouth, although the other method is preferable if we desire to secure a prompt action. In spite, however, of these antagonisms, the net effect is a powerful, prolonged contraction of all the smaller arteries, with a consequent marked increase of blood pressure, going on, *pari passu* with the administration of the drug, to dry gangrene and loss of the extremities, and to extravasation of blood into the viscera.

The effect upon the uterus is primarily due to spinal stimulation by the chrysotoxin, but there is evidently also a direct action upon its walls.

Upon the intestine, the effect of ergot is to increase peristalsis, but at the same time to diminish secretion, as is true of the secretions generally, due to diminished arterial supply.

Uses.—Ergot is chiefly employed as an ecbolic, being given in the later stages of parturition, especially to secure the complete emptying of the uterus, and to check hemorrhage. Formerly it was given at one stage earlier, to favor the expulsion of the placenta, but this practice is now generally discouraged. Against these views are still those of some excellent practitioners who recommend the early moderate use of ergot to promote labor.

Next to this use of ergot, that for checking internal hemorrhages, especially of dysentery, may be considered the most extensive. Its use has been found favorably to affect aneurisms. It is also very largely employed in the relief of headache resulting from prolonged mental activity and excitement, and whenever congestion exists. It also gives marked relief to conjunctivitis of a similar character.

Finally, it will frequently be found to do good service as an aphrodisiac, although in many cases it will fail.

Preparations and Doses.—The unofficial preparations of ergot are exceedingly numerous, and the practitioner should treat them with great conservatism, owing to the possible serious change in property resulting from slight differences in the mode of extraction. Since the cornutine and sphacelotoxin are alcohol-soluble, the ergotinic acid water-soluble, both solvents should be used in the extraction. The official fluid extract, especially if having been found to meet a satisfactory physiological test, made with diluted alcohol, and with the addition of two per cent. of acetic acid, answers every requirement. It may be given in doses of from 2 to 4 c.c. (fl. ʒ ss.–i.); the wine of fifteen-per-cent. strength may be given in doses four or five times as large; the extract ("ergotin") is considerably used in doses of 0.3 to 1 gm. (gr. v.–xv.).

Henry H. Rusby.

ERIODICTYON. See *Yerba Santa.*

ERYNGIUM. See *Umbelliferæ.*

ERYSIPELAS.—(Fr. *Erysipèle;* Ger. *Rothlauf*).* Definition and Etiology. By the term "erysipelas" is understood a disorder of the general system, of febrile nature, cyclic character, and varying severity, which is caused by the introduction, into the body, of a specific pathogenic germ of bacterial form. This is of the streptococcus variety, and was first described by Fehleisen, and for that reason is called by his name.†

The disease is seated upon an epithelial surface, either of the skin or of a mucous membrane. When situated upon the skin, it is characterized by a sharply defined area of redness, which gradually advances to occupy a larger surface, is accompanied by a relatively intense febrile action, and generally terminates in complete recovery, with exfoliation of the epidermis upon the surface which was the seat of the disease. One attack of the disease affords no immunity against recurrence, in the same or another locality, and it may involve the mucous membranes as well as the outer covering of the body. The accounts of some of the earlier of the known epidemics represent a much severer type of disease than the erysipelas of our day.

From a careful study of cases, as well as from experimental inoculations, the period of incubation of erysipelas has been estimated as being not less than fifteen nor more than sixty hours. A specific germ, the streptococcus of erysipelas, is found in all cases of the pure disease and is capable of transmitting the malady to healthy individuals in series. This germ is found in the lymphatic vessels of the skin and in the lymph spaces, and when the culture is pure, it is believed never to produce suppuration.‡

Infection with the streptococcus of Fehleisen produces at the point of inoculation a special inflammation of the integument, external or internal, of which the characteristic tendency is its extension peripherally, until the virulence of the micro-organism is exhausted, or the individual attacked has become immune to the disease.

At present, no difference in character or nature is recognized between erysipelas of the face (so-called "spontaneous" or "medical" erysipelas) and erysipelas following wounds ("traumatic" or "surgical" erysipelas). Contagion is the simple, inevitable, and indispensable cause of the disease.

It is always necessary that there should be a door of entrance for the microbe, and if careful search fails to discover a solution of continuity of the surface of the skin, we must still admit that such an abrasion of either the skin or the adjacent mucous membrane really exists. In certain cases it would seem that the simple absence of epidermis or epithelium is in itself sufficient to allow the entrance of the poison of erysipelas into the system. In this direction the occurrence of erysipelas in young and imperfect cicatrices from recent injuries is interesting. Warren says that it is probable that healthy skin offers a sure protection against infection from erysipelas (*op. cit.*).

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* For the bacteriology of erysipelas consult the article on *Bacteria*, in Vol. I.

† "Die Aetiologie des Erysipels," Berlin, 1883.

‡ Petruschky (quoted by Warren) showed conclusively that a streptococcus cultivation from pus may cause erysipelas in the human subject.

The progress of erysipelas seems to depend upon the extension of the local infection by contiguous growth of the specific coccus, and not by transmission of the infection to distant parts by the circulation. The spread of the disease is usually from a distinct centre by peripheral growth. The appearance of erysipelas in regions distant from the point of original infection has been thought to indicate that the virus may be transmitted by means of the blood current, but this method of spread is not universally accepted. The constitutional disturbance—fever, etc.—accompanying the disease is probably due to the presence in the blood of the toxic products of the specific germ of the disease.

That erysipelas is a communicable disease has been proved by repeated transmission. Warren cites the former frequent conveyance of this disease in vaccination, and quotes the statements of Moreland in the Records of the "Boston Society for Medical Improvement." There is, however, a strong probability that in the former state of surgery, the poison of erysipelas was conveyed by means of hands or instruments not surgically clean, or by the contamination of dressings or other material with the virus of the disease.

The origin of erysipelas upon surfaces covered with mucous membrane is not so easily determined. In the eyes, mouth, and nose it may often be impossible to discover the wound through which entrance to the system was effected, as these mucous surfaces are extensively reflected, or are concealed to a great extent from view.

Erysipelas is comparatively rare before the age of puberty, and still more rare in old age. The associated causes of the disease may include conditions of inanition, poverty, exhaustion, overwork, previous illness, chronic poisoning, cachexia, etc. All these render the entrance of the microbe more easy by diminishing the resistance of the tissues and organs.

Certain individuals present an unusual susceptibility to erysipelas, suffering an attack whenever they are subjected to a fresh exposure. One of the physicians attached to a Paris hospital took the disease each time he had a patient with erysipelas in his service, although he employed all possible precautions against infection.

Pathological Anatomy.—Fehleisen distinguishes three zones in the erysipelatous plaque: a central field, in which the process may be receding, a circle in which the disease is still spreading, and an outer area in which the tissues are in a state of commencing congestion preceding the actual extension of the malady. On section of the tissues there is observed an abundant infiltration of the area with leucocytes, which entirely fill the field, particularly in the vicinity of the vascular channels, around the hair follicles, and in the neighborhood of the sudoriparous glands. The distinguishing characteristic of erysipelas in comparison with inflammatory œdema, is the proliferation of the fixed cells of the connective tissue, due to the specific action of the particular organism of this disease.

Symptoms and Course of the Disease.—The most common seat of erysipelas is the face, and its symptoms will be considered as observed in that location.

The invasion of the disease is accompanied by the general symptoms of septic infection, viz., malaise, headache, anorexia, dryness and a bad taste in the mouth, and occasionally vomiting. The chief symptom, however, and one which is never absent, is the initial chill, sometimes slight, but often very severe. This is sometimes repeated, but usually it consists of one prolonged rigor. The severity of the disease seems to bear some relation to the severity of the premonitory chill as regards duration and intensity. The chill is soon followed by fever of an intense character, with elevation of the temperature, often to 104° F. or even above that figure. The patient is frequently delirious. In erysipelas of the face, there are tumefaction and tenderness of the submaxillary lymphatic glands before other local symptoms of the disease are apparent. In some cases this precedes the exanthem by from one to several days. The adenopathy would seem, however, to be necessarily secondary to the local infection and its primary local processes, though the glands are possibly invaded by the micrococcus before the disease has made itself evident at the seat of invasion. The glands are sometimes painful even before there is any apparent increase in their size.

The first onset of the visible disease is in the form of an acute dermatitis, situated at the angle of the eye, at the naso-labial fold, at the nasal orifice, about the ear, or in some other location about the face or head. In a few hours a plaque of erysipelas is formed which rapidly enlarges and acquires double its first dimensions within twenty-four hours. The part affected presents a color which varies from bright scarlet to dull rose. In anæmic patients the tint is only a rosy blush. Pressure by the finger dulls it, but the color at once returns. The skin becomes tense and glistening. The temperature of the affected part is higher by from one to four degrees than that of the opposite side. There is a sensation of burning heat, and sometimes there is also considerable local pruritus. The entire plaque is elevated on account of the swelling of the skin, and its borders are sharply defined. The maximum intensity of the disease will always be found at the border of the patch, as at this point the malady is extending, while at the centre of the plaque it may be subsiding or already healed. The pain accompanying the advance of the disease is in inverse ratio to the tumefaction of the tissues; the loose structures in the vicinity of the eye allowing much swelling without great pressure, while the tense tissues upon the scalp cannot yield to pressure, and the suffering here is consequently more intense. The erysipelatous inflammation extends slowly from the periphery of the plaque, in all directions, and its advance has been compared to the spreading of a drop of oil on paper. In this way the disease may invade the greater part of the face and forehead, but it rarely extends over the surface of the chin. In a recent case seen by the writer, however, the inflammation passed from the lips to the chin on both sides of the neck, and induced great difficulty in swallowing. At the same time the face showed very marked deformity. In some instances the disease may render the patient quite unrecognizable, and breathing may be embarrassed from the swelling in the nares. The eyes may be quite closed, and the sufferings of the patient may become intense. The scalp is frequently invaded, but the disease seldom passes the line between the head and neck. The invasion of the hairy scalp is usually accompanied by severe headache and delirium, which may alternate with dulness or coma. These symptoms are thought to be of reflex character and due to irritation of the branches of the fifth pair of nerves. Nervous phenomena are much more frequently observed in alcoholic subjects.

The general character of erysipelas remains the same, though different terms have been applied to express particular features of its progress, such as "fixed," "serpiginous," "vague," "migrans," "ambulant," "phlegmonous," etc., as observed in erysipelas of the trunk, limbs, face, etc.

The variety of erysipelas which is called "phlegmonous" is characterized by the spread downward of the disease into the deeper subcutaneous tissues. The infection is much more extensive than in ordinary erysipelas, and the quality of the virus may be more virulent; the local symptoms are consequently more distinct. The fever continues high, and is often typhoidal in character. It is not long before suppuration takes place. Free incisions give vent to abundant discharge, in which may be found shreds of necrotic tissue. Large sloughs are eventually discharged. The pus burrows rapidly, to considerable distances, under the skin, which is thus dissected off from the subjacent structures. In rare cases suppuration may extend more deeply still and penetrate the intermuscular spaces. Even the periosteum and bones may become infected, and cases are recorded in which the joints have been involved and have become disorganized. In the extreme forms of this last type, large masses of tissue may become gangrenous, and at times there is emphysema of the parts from the formation of gas in the tissues, owing to the decomposition of the necrotic and sloughing tissues. The simplest case of facial erysipelas may without apparent cause assume the phlegmonous form, and be followed by the most disastrous consequences. The disease may extend to the eyelids, and orbital suppuration may occur with infection of the eye itself. Blindness is not an infrequent result of this complication. Septic meningitis may also follow erysipelas in this location.

As already stated, erysipelas occasionally involves the mucous membranes. In the faucial form of the disease there may be extension to the pharynx, and thence through the Eustachian tube to the cavity of the middle ear, whence it may pass through the drum membrane to the external auditory meatus and to the scalp. It may be traced internally as far as the lungs. Should the glottis become œdematous, as it occasionally does, the result is usually rapidly fatal. The other natural openings of the body are also occasionally the seat of this disease.

Strauss has recognized a pulmonary erysipelas. This generally occurs subsequently to an erysipelas of the face or throat, and is marked by insidious development, without chill, and by a rapid extension.

Erysipelas may also extend from the face or other point of primary attack to the digestive tube. Rendu has reported a case in which the disease was thought to have extended through the alimentary canal, and appeared at the anus, where it caused a perineal abscess. In 1887 Heidenreich published a case of erysipelas of the right thigh which had extended to the intestine by way of the anus. Ivanowski made an autopsy of a case of intestinal erysipelas which had been propagated from the perineum through the entire large intestine. To our knowledge these are all the reported observations of this complication.

Pericarditis and endocarditis have also been reported as complications of erysipelas, and the specific germ has been recovered from the blood and from the fluid in the pericardium. In this complication the path of the infection is no more clear than in rheumatic invasion of the heart or its coverings. The results depend on the amount of damage to the valves or on the other changes effected. Lesions of the kidneys are among the most frequent complications; albuminuria is generally present at some stage of the disease, but is usually transitory in character, and disappears with the recovery of the patient. Its presence or amount bears no relation to the elevation of temperature or the pulse rate. The urine often contains blood elements and epithelial and hyaline casts. Bacilli are often present in the urine; they may be due, as indicated by Professor Bouchard,* to the infectious nephritis.

Peripheral neuritis, pleurisy, and peritonitis have also been noted as complications of erysipelas.

Erysipelas in open granulating wounds often causes comparatively little disturbance. The disease sometimes appears to exert a stimulating effect upon the healing process, the part closing more rapidly than before.

There is no regularity in the temperature curve of erysipelas. Oscillations of slight extent coincide with grave forms of the disease, though there seems to be no direct relation between the degree of elevation of temperature and the extent of area comprised in the erysipelatous process. A constant elevation without irregularity usually precedes a fatal termination. The temperature may even rise after death. Usually when the progress of the disease is arrested, there is a rapid fall of temperature. This critical fall may appear at any time between the fifth and the tenth day. In severe cases the fall is usually by lysis.

Diagnosis.—The diagnosis of erysipelas may be difficult in the absence of indications of efflorescence, as in cases in which the seat of the primary infection is in the nasal fossa or in the interior of the mouth; but the high fever and the swelling and tenderness of the submaxillary glands are valuable indications of the character of the disease, and the absence of other causative agencies should lead to a suspicion of the infection even before the efflorescence is evident.

When the disease is situated upon the external surface of the body it is hardly possible to mistake it for any other malady. Erysipelas may be confounded with simple lymphangitis. The former is, however, always accompanied by inflammation of the lymphatic channels and glands. In simple lymphangitis there is swelling in the course of the lymph channels, but there is no typical inflammation of the skin with peripheral extension and central recrudescence; there are also less tumefaction of the skin and less elevation of the temperature, and the surface is not dry and glazed as in erysipelas. In lymphadenoma, and in malignant diseases, there is often induration of the glands in the vicinity, but there is absence of fever, and the course of these diseases is chronic; other signs of systemic disease, such as cachexia, emaciation, etc., are also usually unmistakable. The various forms of erythema may present some degree of resemblance to erysipelas, but this lesion is seldom confined to a single point, is not accompanied by glandular induration, and is usually disseminated over the surface of the body and limbs. Herpes zoster may simulate erysipelas to some degree, but the course of the disease will soon determine the difference. Certain drug eruptions may present appearances similar to those of erysipelas, but it is usually possible to trace their origin to the irritating substances which have produced them. Glanders presents many appearances similar to those which characterize erysipelas, when developing, but this disease is accompanied by a hard œdema, is not distinctly defined, and the skin is not so raised at its borders. At the end of a few days, the development of pustules upon the surface affected will distinguish it from erysipelas.

Prognosis.—The prognosis of erysipelas is on the whole favorable. After a few days of inflammation there is a marked tendency to resolution; and this simple fact should be borne in mind in estimating the value of any remedy. The disease varies greatly in severity, but it may be said that the danger from the disease itself is less than that which attends its complications.

If the disease attacks the mucous membrane as in the throat, it will probably be severe; if the vagina is the point of origin, as in puerperal cases, there may be great reason to fear pyæmia or septicæmia. The late Dr. Oliver Wendell Holmes was among the first to recognize the frightful conditions arising from puerperal infection, and openly laid the tremendous mortality of that disease to the introduction of erysipelas into the system of the parturient woman. "The work for which Holmes will always have a place among those who have advanced the art of healing and thus deserved well of humanity, is his demonstration of the infectiousness of puerperal fever, read before the 'Boston Society for Medical Improvement' in 1842. He was not the first to preach this doctrine, but to him belongs the credit of having forced men to listen to the truth" (*The Practitioner*, vol. lxvi., 1901, page 77). The further discussion of the relations of erysipelas to puerperal fever will doubtless be found under the latter heading, in a later volume of the present series.

The deeper-seated types of the disease, such as the phlegmonous or gangrenous, have undoubtedly a higher mortality than the cutaneous forms. In individuals enfeebled by long-standing suppuration, and in alcoholic subjects the disease may prove a formidable complication. The same may be said of a number of organic diseases, such as diabetes and Bright's disease, particularly in advanced life. For similar reasons, youth and old age are periods of life when the patient is less resistant to its influence than when in the prime of life. Erysipelas is distinguished among acute diseases for its tendency to relapse, but the relapses are usually not so serious as the initial attack. This may be due to a diminished virulence of the contagion or to the fact that the system is protected to a certain extent by the secretions of the streptococci (antitoxin?), which may increase the resistance of the body or tissues to the poison of the infection.

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*See also a valuable reference by Salinger in Medical News, July 4th, 1891.

The ordinary duration of erysipelas varies from a few days to two or three weeks, according to the extent to which it spreads over the surface of the body. The tendency is notably toward recovery, but occasionally patients succumb from exhaustion, from the systemic poisoning caused by the toxins of the disease, or from meningitis, when the infection extends to the membranes of the brain, from the ear, the lining of the nose, or the frontal sinus.

Erysipelas of the new-born is generally acquired by infection from the navel, and usually leads to a fatal result.

The curative influence of erysipelas when it occurs in the course of other diseases has been already noticed. Chronic inflammations of the skin, particularly those of a tuberculous or syphilitic character, have been reported as benefited by an intercurrent attack of erysipelas, after resisting all other modes of treatment. Sarcoma and carcinoma have also been relieved or cured by the same influence.* Old and refractory neuralgias have often been cured or greatly relieved through the same means. In the insane, likewise, a temporary improvement has occasionally been observed.

This effect is supposed to be due to a change in the nutrition of the cells of the morbid tissues, or to a direct destructive influence upon the elements of the foreign growth by the micrococci of erysipelas. This ingenious theory needs the support of more extensive observation for its entire confirmation. At the present time one would naturally hesitate to employ so serious a measure as the voluntary infection of the system of a human being with the virus of erysipelas for a doubtful therapeutical purpose.

In like manner, the effusion of fluid within the thorax, following an acute attack of pleurisy, has been observed rapidly to diminish, and at times to undergo complete absorption, as a sequence of an invasion of the skin of the chest and trunk by erysipelas.

TREATMENT.—The treatment of erysipelas is chiefly to be directed to the complete isolation of the patient from all other sick persons, and the employment of all possible means for the establishment of good sanitary conditions about the patient. This includes scrupulous cleanliness, pure air, pure water, sunshine, and the rigid antiseptic treatment of existing wounds or other lesions. The local symptoms may be treated according to the varying requirements of the case.

The most rigid prophylaxis should be carried out; the patient should be isolated, and all possible means be employed to restrict the spread of the disease by soiled dressings, infected linen, or other articles. All these things should be burned at once.

The general treatment is the same as that commonly employed in other infectious maladies. The large number of remedies which have been recommended for erysipelas may be of service in ameliorating certain symptoms, but they are in no sense specifics for this disease. Aconitine (crystallized), in doses of 0.25 mgm. every six hours, or 0.1 mgm. every two hours, has been thought to reduce the duration of the disease and to alleviate the pain.

As regards the local treatment there are various procedures which may be used to advantage. Compresses dipped in some lotion of a cooling nature and applied to the inflamed skin usually afford considerable relief. Painting the part with tincture of iodine, with nitrate of silver, with carbolic acid in weak solution, or with corrosive sublimate in dilution of one-tenth of one per cent., has proved helpful in certain cases. Favorable results have been obtained by spraying the affected surface with a solution of corrosive sublimate in ether, in similar dilution. Under treatment of this kind the disease has apparently ceased to advance, and the inflammation has subsided in from twenty-four to forty-eight hours. Painting the borders of the affected area and the sound skin adjacent to it with contractile collodion has been a most prompt and satisfactory method of treatment in the hands of the writer, the disease seldom crossing the line of collodion; or if it has not been entirely subdued by the first application, it has generally yielded to a renewed and more extended "fencing in" by the same means.

Subcutaneous injections of carbolic acid have been highly recommended as an almost specific treatment for erysipelas, and often its use in this way has been followed by the most favorable results. The frequent application of carbolized oil relieves the sensation of burning and stiffness, and is generally very soothing in its action. White paint has been used in the same way. Frequent or sudden changes of temperature in the sick-room should be avoided, and if a "cold" is contracted it is liable to aggravate the inflammation.

When sloughing or gangrene occurs, the case must be treated according to general surgical principles—*i.e.*, by free incisions, drainage, etc.

Cool baths may be employed for the purpose of diminishing the general temperature of the body, and the internal administration of the salicylates has sometimes been of service in accomplishing the same result.

Treatment by large doses of tincture of the chloride of iron (twenty to sixty drops in water at intervals of three to six hours) was at one time highly esteemed as almost a specific in erysipelas; but its use has been almost discarded since the increased knowledge of later years as to the nature of the malady, and the introduction of antiseptic methods in its management. Many other forms of drug treatment have been abandoned for the same reason, and to the great advantage of the patient.

In the phlegmonous form of erysipelas it is important to recognize suppuration as early as possible. It is in these cases that prompt surgical interference may be productive of the best results. The tendency of the infection to spread along the spaces separating the bands of loose connective tissue must be corrected promptly, no matter how long or how numerous the incisions may have to be. Very hot and large antiseptic poultices are now indicated, and they should be often changed. The graver forms of gangrenous erysipelas with malignant œdema should be dealt with promptly and heroically by long and deep incisions. Many a life has been saved by the timely action of the surgeon.

In phlegmonous erysipelas of the face, pus often forms in the tissues of the orbital cavity, necessitating incision between the eye and the orbital margin. In scrotal erysipelas of a phlegmonous or gangrenous character, a free incision should be made through the raphé, completely dividing all the tissues involved. This incision usually results in the prompt arrest of the inflammatory process, and the wound generally heals rapidly.

During the period of convalescence the treatment should be tonic and supporting; and care should be taken to avoid chilling of the surface of the body and fatigue. So long as desquamation lasts isolation should be continued, and in private practice the patient should not be allowed to mingle with other members of the household, particularly during periods of epidemic disease, until it is tolerably certain that the micro-organisms of the disease have been completely eliminated from the system.

Cases of this disease should be visited by the surgeon after he has seen all other patients, and the hands and instruments should be thoroughly cleansed and disinfected afterward. The patient should not be considered safe from a recurrence of the disease, nor should the precautions against infection of other persons be relaxed, until the disease has entirely disappeared from every portion of the body which was at any time invaded; and the danger of a relapse or of communicating the disease to others is not entirely absent until the process of desquamation of the epidermis in the regions affected by the erysipelatous inflammation has been completed. When the skin has fully returned to its normal condition, it is advisable that the entire surface of the body should be carefully bathed in warm water, made alkaline by means of sodium bicarbonate and perceptibly impregnated with carbolic acid. A complete attire of fresh and uninfected clothing should replace the clothes previously worn. The patient may then be allowed to go at large.

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* See the various contributions to this subject by Dr. Coley and other investigators.

One of the remoter dangers associated with erysipelas, —a danger, however, which is not of frequent occurrence —is an interference with the function of the kidneys. This complication may assume a variety of forms, and its presence as a complication of the erysipelatous process is of sufficiently grave importance to make the daily examination of the urine advisable. The renal condition often seems due not so much to the specific character of the erysipelatous infection, but rather to the action of the toxic products of the bacilli which accompany the graver forms of the disease. Should this or any other unusual complication arise in the course of erysipelas, the same rules should be observed and the same measures adopted as in other cases of similar disturbance of these important organs. The strength of the patient should be carefully husbanded, and tonic measures should be cautiously employed to support the system until the natural vigor shall have been re-established. For this purpose the diet should be carefully selected, and should consist of nutritious but unstimulating food, with the addition of some of the artificial digestive ferments if the functional ability of the alimentary organs has been seriously impaired. A very excellent addition to the ordinary diet of a weak and debilitated patient is the extract of malt in some of its more acceptable forms. Perhaps the best preparation at present for this purpose is that known as "Amê," or the Japanese extract of rice. It is of pleasant taste and possesses great nutritive power.

To overcome the debility often remaining after a prolonged attack of erysipelas, a change of scene and climate is often of great service. Excessive fatigue or prolonged bodily exertion should be prohibited, and the patient should be directed to pass a portion of each afternoon in a reclining posture, and if possible to obtain an hour's sleep in the middle of the day. In cases in which the attack of erysipelas is followed by the formation of abscesses, a sojourn at some of the watering-places, particularly at one of those whose waters are of an alterative and chalybeate character, is often of much benefit.

Albert N. Blodgett.

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ERYTHEMA.—The term erythema is a general one for certain diseases of the skin in which there are evidences of hyperæmia and passive inflammation.

Erythema simply means redness, and is therefore nothing more than a symptom, and, used without a qualifying adjective, has but little definitive value.

The definition of erythema, as given by some authors, is "a localized congestion, accompanied by redness, which disappears under pressure."

Two divisions of the subject are usually made, viz., Erythema hyperæmicum and Erythema exudativum; these are again subdivided according to symptoms.

The first general division, ERYTHEMA HYPERÆMICUM or *Simple Hyperæmic Erythema*, is that form of the disease which is characterized by various-sized and various-shaped points and patches of redness, exhibiting no evidences of inflammatory exudation.

The patches readily disappear upon pressure.

The causes of the affection are numerous: heat, cold, the presence of irritating substances, as well as certain general systemic disorders.

It occurs both idiopathically and symptomatically.

The *Idiopathic Hyperæmic Erythemas* are those which are produced by cold or by heat, by traumatism, or by the application of some irritant to the surface of the body.

If the skin be exposed to any of these agents for a great length of time the condition passes from the simple hyperæmic into the exudative stage. Slight sunburn is perhaps the mildest type of hyperæmic erythema. Artificial heat may produce the same condition (*Erythema ab igne*).

Cold will also produce a certain amount of congestion (*Erythema pernio, chilblain*).

Wounds and contusions, pressure of clothing or bandages, also cause a localized erythema.

Exposing the skin to irritating substances, as mercury, iodoform, certain dye stuffs, or poison ivy can cause an erythema.

The *Treatment* for simple erythema is upon general lines. If it is caused by pressure of clothing or from the chafing of two opposing skin surfaces (Erythema intertrigo), remove the pressure and apply some soothing dusting powder.

If it has become almost eczematous in character, and the diseased area is covered with a sticky exudation, as is often the case in infantile intertrigo, Lasar's paste, calamine lotion, made with the stearate of zinc instead of the oxide, or any of the other external applications for eczema, are indicated.

If the erythema is from the external application of drugs, the treatment is obvious; remove the cause.

The *Symptomatic Erythemas* are important, because they so often simulate more serious affections. They generally occur as the result of some derangement of the digestive tract, and are more frequently seen in children or young people. They may also accompany certain systemic diseases, such as diphtheria, scarlet fever, cholera, uræmia, Bright's disease, etc.

The eruption may be found on any portion of the body, although the face seems to be the part most frequently affected. The lesions appear in various shapes; patches, spots, rings, etc., small reddish pea-sized spots called roseola, are often seen in the beginning of a syphilitic rash, smallpox, or as an accompaniment of vaccination, and in some cases of jaundice.

The persistent or fugitive flush seen in rheumatism, asthma, goitre, hemiplegia, is an erythema produced by some impairment of the central or peripheral nervous functions.

The symptomatic erythemas occur in both the hyperæmic and the exudative varieties; and, as they are more frequently observed after they have passed into the inflammatory stage, to save space they can be more conveniently discussed here, before considering the distinct group of erythema multiforme.

Erythema Diphtheriticum.—During an attack of diphtheria, especially if severe, there often occurs upon the thorax and abdomen a diffuse eruption, sometimes extending over the extremities; it may be mottled, punctate, or scarlatiniform in character. The rash usually appears on the second or third day of the disease and should be distinguished from the toxic maculo-papular erythema multiforme which appears late in the course of diphtheria.

Since the introduction of antitoxin as a therapeutic measure a form of erythema has been noted; it occurs chiefly on the trunk, making its appearance from six to twenty-four hours after the injection. This epiphenomenon is regarded by bacteriologists to be due to some idiosyncrasy of the horse from which the antitoxin is taken and not to any defect of the preparation itself. This erythema is not of any grave importance, but is a disagreeable accompaniment of the most effective therapeutic measure in the treatment of diphtheria.

Erythema Cholericum.—This is a polymorphous, maculo-papular erythema seen in some cases of cholera. The eruption first appears on the hands and feet, extending to the forearms, legs, and trunk, and finally to the face. It usually begins early or late in the disease, lasts several days, and disappears by desquamation.

The erythema of *Uræmia* is of the maculo-papular variety. The first lesions are bright red macules which rapidly change into papules, and are generally upon the extensor surfaces of the hands, forearms, and legs. The eruption may extend over the body, even involving the palms and soles; it runs its course in three or four days and subsides with flaky desquamation. When this cutaneous manifestation is seen as an accompaniment of nephritis the prognosis is grave.

In *Chronic Bright's Disease* the erythema consists of bright red macules, generally situated on the trunk, although the neck, arms, and thighs may be involved, and more rarely, the face, hands, and feet; it is accompanied by no subjective symptoms and lasts but a few days.

There is another eruption seen in Bright's disease which is papular throughout. This, I think, is the commoner form. The lesions are large, discrete papules, of a dark red color, generally springing from dry, rough, or scaly patches. The outer side of the thighs and extensor surfaces of the legs and arms are the parts involved.

Erythema Scarlatinoides.—In 1851 Hardy described a cutaneous roseola which closely resembled scarlet fever. He named it Erythema scarlatinoides. Later, Bazin reported similar cases; he applied to them the term erythema scarlatiniforme. Still later, Besnier gave the disease careful clinical and histological study, and from his researches he considered the proper name to be the one first given by Hardy.

Its close resemblance to scarlet fever makes it a disease of considerable importance.

The eruption comes on with slight constitutional disturbance and with more or less elevation of temperature; its advent may be sudden or gradual; it appears first on the chest, as a bright red punctate erythema, and from here eventually spreads over the entire body. Cases have been reported in which it appeared as a diffuse general rash. It is often accompanied by burning and itching; the duration, in either case, is short; it soon becomes pale, and in a few days passes off with little or no desquamation. If, however, the attack has been severe, the desquamation may be considerable, the epidermis shedding itself in large patches.

The disease has no specific infectious origin; it is neither contagious nor transmissible. It differs from scarlatina in the absence of the characteristic strawberry tongue and the typical throat symptoms.

Gastric and intestinal disorders seem to be the prominent causative factors. According to the reports the disease has been observed during the puerperal period and as a symptom of septicæmia. It has also been observed in typhoid fever; in which disease it usually occurs at the end of the first or at the beginning of the third week of the fever.

The external application of drugs, such as mercury or iodoform, has been known to produce the eruption.

In treating the disease such measures should be adopted as the symptoms demand.

Erythema Scarlatinoides Recidivans.—This is a variety of scarlatiniform eruption that tends to relapse, each attack clearing up with considerable desquamation. The disease has been described by the French authors, and many American dermatologists have also reported undoubted cases of this affection.

The term desquamative relapsing scarlatiniform erythema is the name by which the disease is now known. Some of the French writers consider it different from Erythema scarlatinoides because of its extremely inflammatory character, and have suggested the term Dermatitis scarlatiniformis.

The symptoms as given by Besnier are as follows: It often begins with shivering, lassitude, sore throat, headache, and elevation of temperature. When the rash is at its height the fever will suddenly cease. The eruption lasts for from four to six weeks, and is similar to that of scarlet fever.

Desquamation often begins on one part of the body while the efflorescence is present on others.

The etiological factors are numerous: it may be due to external or internal causes; it has been observed in certain diseases such as rheumatism, gonorrhœa, toxæmia, etc.; mercury, quinine, belladonna, antipyrin are among the drugs which produce this variety of erythema.

One attack predisposes to another, recurrences usually taking place at the change of seasons. While any of the foregoing factors may produce an attack, yet what induces an outbreak in one person will not in another, and attacks in the same subject may be brought about by entirely different causes.

It has been observed that each subsequent manifestation of the disease tends to become milder.

In making a diagnosis, erythema must be differentiated from scarlet fever, which disease it most closely resembles. The principal points to be remembered are: while there may be sore throat at the beginning of the attack it is not so severe as that of scarlet fever, the strawberry tongue is not present, the temperature abates during the height of the rash, the duration of the disease is more variable and prolonged, and, finally, it is non-contagious and tends to relapse.

Erythema Perstans.—This is a type of erythema which has many of the eruptive characteristics of Erythema scarlatiniforme, differing in that the rash may persist for weeks, months, or longer. The eruption is symmetrical and is attended by severe subjective symptoms, as pain and itching.

The treatment of this group of erythemas depends largely upon the cause; if it is due to some systemic disease, treat that, or if to external irritation, remove the irritant. Locally, soothing applications will be found useful.

In the perstans variety, Duhring recommends the exhibition of quinine, sodium salicylate, or ergot in full doses.

ERYTHEMA EXSUDATIVUM MULTIFORME.—The affections grouped under this general head are characterized by inflammatory changes in the skin, and are in contradistinction to the simple congestive or hyperæmic erythemas. As the name implies, the lesions are multiform, and the symptoms and etiology are varied. The French term it *Erythème polymorphe.* The general type, erythema multiforme, was clearly described by Hebra; since then the question is constantly brought up whether many of the cutaneous manifestations grouped under this head are not really distinct diseases.

It is an inflammatory affection characterized by reddish or variegated macules, papules, and pustules. The eruption occurs either discretely or in patches, with sharply defined, marginate outlines, and runs an acute course. The patches may be simply erythematous or may consist of maculo-papules, papules and vesicles, and, in some instances, of vesicles and blebs.

The lesions pass rapidly through their various evolutions: first, the erythematous patches are red and clearly defined from the surrounding skin; in a few days they begin to assume a purplish or bluish-white color, which disappears upon pressure.

The various shapes, colors, and character of the patches have given rise to the terms circinatum, annulare, papulosum, iris, marginatum, purpuricum, urticans, etc.

The eruption which fades in the centre and extends peripherally is termed circinatum. If there are a series of concentric rings formed it is called Erythema annulare.

Erythema iris is a rare manifestation of Erythema multiforme, and has been described under various names, such as Herpes iris, hydroa, Herpes circinatus, etc.

Two varieties are most frequently seen: in one the lesions are vesicular and bullous, arranged in clusters and rings; in the other they are vesicular throughout. The degree of redness is marked, assuming in most cases many hues, from which comes the term iris.

The eruption is generally located on the backs of the hands and feet, although it may invade other parts of the skin, even the mucous membranes.

Marginate erythema is simply that form in which the margin is sharply defined. The gyrate and figurate forms are those in which the patches and circles merge together and form fantastic shapes.

Papular erythema is the name given to the disease when the patches consist of papules or maculo-papules.

If the erythema is complicated with cutaneous hemorrhages it is called *Erythema multiforme purpuricum*; if with urticarial wheals, *Erythema multiforme urticans*.

Erythema multiforme attacks by preference certain regions of the body; the backs of the hands, forearms, and legs being the localities generally invaded. In some cases the face may become involved. The eruption occurs symmetrically, and the outbreak usually begins first on the hands and fingers. If it attacks the face the first lesions are seen on the forehead.

Cases have been recorded in which the eruption involved the whole cutaneous covering, beginning in the favorite locations and spreading over the entire body, finally resolving by exfoliation. The disease, in these instances, closely resembles Dermatitis exfoliativa (see Erythema scarlatiniforme).

The subjective symptoms are mild, and the patient may complain only of slight burning and itching. The systemic symptoms are variable; frequently there will be considerable eruption over the hands and feet, with no general discomfort. Again there may be a marked elevation of temperature, preceded by malaise, headache, rheumatic-like pains, sore throat and swelling of the joints.

Gastric and intestinal derangements have been noted in the severer cases.

The evolution of the disease is varied. Often erythema will be the only eruption observed throughout the whole attack, while in other cases there will be vesicles or aborted vesicles. Again the lesion may be maculo-papular. Sometimes the patch will clear in the centre and form opalescent rings. In the more serious cases there may be a diapedesis of blood in the skin. If this is great enough to form distinct purple spots, it is a question if the disease is not Purpura rheumatica, and not a true Erythema multiforme. It is now almost the universal belief that in its etiology and pathology Erythema multiforme is closely allied to the cutaneous lesions of rheumatism. Erythema multiforme is a disease of spring and autumn, although it may occur at other times of the year. Humidity or dampness seems to favor its development. Women, especially young women, are more subject to it than men.

Pathologically it is an angioneurosis, the effect being primarily upon the nerves, secondarily upon the blood-vessels. It is believed by many authorities to be of an infectious nature, although opposing theories appear to be equally well grounded in fact. Cases have been reported of nervous shock followed by an erythematous outbreak.

Microscopical examinations of the lesions show a dilatation of the vessels of the stratum corneum and some exudation of white corpuscles.

Recent observations have not been able to demonstrate the presence of emboli in the cutaneous vessels, although some pathologists claim to have found them.

The *Diagnosis* of the disease is comparatively easy, providing the multiform character and peculiar color of the lesions are borne in mind. The presence of the lesions upon the hands and feet, and the almost total absence of itching will serve to distinguish it from urticaria.

In papular eczema the papules are smaller and intensely itchy. The course and symptoms of pemphigus will aid in diagnosing it from the bullous form of erythema.

Erythema nodosum will be known from Erythema multiforme by the presence of bluish nodes on the extremities. The differential diagnosis between Erythema multiforme and Dermatitis herpetiformis is more difficult to make. Careful study, alone, makes differentiation possible. Limited space will allow only a brief outline here. Dermatitis herpetiformis is a chronic disease, and tends to relapse, each recurrence showing the herpetiform character of the lesion; Erythema multiforme is an acute disease, occurring as a rule in the spring and fall, and while in some instances the lesions may be herpetic-like, they always present more or less multiformity.

The *Treatment* of Erythema multiforme should be on general lines. At the beginning of the attack a saline purge is indicated; the diet should be light and nutritious; stimulants of all sorts should be avoided; antirheumatic remedies, such as the salicylates, appear to give the best results. In the relapsing cases quinine and iron should be used. Astringent washes, such as lead lotion, will be found useful in treating the skin lesions. If there should be itching a weak solution of carbolic acid or menthol will give relief. Some authors recommend various pastes containing a small per cent. of carbolic acid, resorcin, or salicylic acid.

In the beginning of the disease the *Prognosis* as to duration should be very guarded, for relapses may occur that would prolong the attack indefinitely. Generally the disease runs a definite course, lasting from a month to six weeks, treatment seeming to have very little influence upon it.

ERYTHEMA NODOSUM is an inflammatory disease of the skin characterized by various-sized elevated nodes of a rosy red or purplish color.

The disease is generally ushered in with some systemic disturbance; there are malaise, fever, and rheumatic-like pains of the joints.

The nodes begin as dark indurated patches, they appear suddenly and rapidly arrive at full development. Various regions of the body may be involved, although the extensor surfaces of the arms and legs are the parts usually affected. The nodes differ in size from a filbert to a large English walnut. At first they are bright red, gradually growing darker until they become purple, finally fading to a yellowish-blue tint resembling the discoloration of contusions, which has given rise to the synonym Erythema contusiforme. Throbbing and pain on pressure are characteristic symptoms; frequently the nodes become so inflamed and shiny that they are mistaken for points of suppuration. The number of the nodes vary; sometimes they are limited to two or three, then again there are four or five times as many. They appear in successive crops, each crop being accompanied by more or less systemic disturbance. Cases have been reported in which there were diarrhœa, high temperature, and vomiting.

The cause of the disease is not clearly determined, although it is most frequently met with in the anæmic and weakly; good general health does not preclude an attack. Exposure to cold in some cases seems to provoke an outbreak. Females appear to be more subject to the disease than males—the proportion being about three to one. It is more frequently seen in early middle life, although I have observed it in people over fifty years of age.

The pathology is that of an exudative inflammatory process, similar to Erythema multiforme. Some authors claim it to be an inflammation of the lymphatics; others, that the nodes are inflammatory infarcts. Many competent observers consider it to be closely allied to Purpura rheumatica. The justice of the claim that it is of infectious origin merits more than passing notice; for if the course and symptoms are closely observed it will be found that it bears a marked resemblance to some of the infectious diseases; as for instance influenza.

There seems to be no doubt that Erythema nodosum is in some way closely allied to rheumatism, for the joint and muscular pains are quite similar, and heart involvement has been noticed during a course of the cutaneous disease. It is probable that when the bacteriology of rheumatism is more fully worked out it will be found that Erythema nodosum is due to the same or a similar organism.

The microscopical findings are similar to those of Erythema multiforme. The capillaries are dilated; there is an infiltration of blood cells into the derma, and the lymphatics are filled with cells. Competent observers have failed to demonstrate free cutaneous hemorrhages in the contused areas.

In diagnosing the disease care must be taken not to mistake it for bruises; it is sometimes diagnosed as erysipelas, especially if it occurs about the face. The nodes have been cut into under the impression that they were abscesses. The number and sites of the nodes will help to distinguish it from syphilitic gumma. Giant urticaria differs from erythema in that it is never accompanied by rheumatic-like pains or by fever. The color of the lesions differs, the erythematous nodes are painful, while the wheals of urticaria are itchy. The course of the two diseases is dissimilar; erythema nodosum lasting two or three weeks, while urticaria disappears in a few days.

It might be mistaken for that rare disease Erythema induratum, but this affection runs a slow chronic course, generally terminating in ulcerations.

The distinguishing characteristics of phlebitis, lymphangitis, and Erythema multiforme should also be borne in mind.

Treatment.—The treatment is according to the symptoms. If there is much fever antipyretics are indicated. The bowels should be kept open and a simple diet should be prescribed. As regards the general therapeutics, the most reliance should be placed upon salol, salicylate of soda, or quinine; phenacetin, combined with any of the above, aids in relieving the muscular and joint pains. It is well to follow this line of treatment with liberal doses of iron and tonics, especially in weak females. External lotions of lead water and opium relieve the burning pain, or, if preferred, a ten to twenty-five per cent. ichthyol ointment can be used.

The *Prognosis* is favorable; relapses are rare.

ERYTHEMA ELEVATUM DIUTINUM.—In 1894 Crocker described a disease to which he gave this provisional name. The eruption occurs in young girls of rheumatic history, and chiefly affects the hands, lips, knees, and buttocks. The lesions are pale, purplish-red in color, and in some cases are sharply defined, in others nodular and irregular in outline. They are firm to the touch and painful when pressed upon. There are few or no subjective symptoms. Cases have been reported in which there was considerable disfigurement from the eruption, the skin being so nodular and infiltrated. The lesions tend to persist, but may undergo gradual involution. Those that do remain become as hard as cartilage. Microscopically there are evidences of inflammatory processes followed by the production of fibrous tissue. It is undoubtedly a mistake to use the term erythema in this disease, for it does not properly apply to the condition, hypertrophic changes being the chief pathological element. The proper classification will be finally decided after further study, but until then it is as well to describe the disease under this caption as elsewhere.

ERYTHEMA INDURATUM, or *Erythème induré des scrofuleux,* is a disease first described by Bazin. It is a deep-seated nodular eruption situated in the skin over the legs and fingers.

The nodes vary in size, and are round or oval in shape; as a rule they are few in number, but cases have been reported in which they became confluent. They run an indolent course: some disappear by spontaneous involution, while others suppurate or become necrosed, forming deep circular ulcers. Pain, which may be present, is not severe. Young strumous girls with feeble circulation seem to be especially subject to the disease.

In diagnosing this disorder Erythema nodosum and syphilitic gummata must be thought of. It differs from Erythema nodosum in that the lesions are more circumscribed, firmer, and of a darker color; they are more deeply situated in the skin and less tender; they run a chronic course and tend to ulcerate.

Syphilitic gummata are not bilateral, and the patient gives no evidences of other specific symptoms.

Treatment consists of change of air, tonics, and rest in bed. *James Macfarlane Winfield.*

ERYTHRASMA.—This is a cutaneous *disorder* rather than a *disease* of the skin strictly speaking, and is due to the presence and growth, *on* and *in* the superficial layers of the epidermis, of a vegetable parasite. The affection was first described by Burckhardt in 1859 and by von Bärensprung in 1862, who then named it. Later it was studied by Besnier, Balzer, Dubreuilh, Riehl, Crocker, and many others, who all agree that it is a distinct affection. It is an extremely rare though trivial affection; it produces no inconvenience and is usually only accidentally discovered. During the past six years no instance of it has been noted in the dermatological department of the Vanderbilt Clinic, New York City, where the examinations, at least amongst the male patients, in whom it is said to be most common, is of the most open kind. The parts attacked are primarily those situations of the body—such as the axillæ, the inguinal and genito-crural regions, and the cleft of the nates—where, the apposed surfaces of the skin coming in contact, warmth and moisture are most constant. To these situations the parasite may confine itself indefinitely, but sooner or later (if uninterrupted in its course) the growth spreads slowly to contiguous parts and the trunk and limbs become invaded. These parts, however, may be attacked independently. The affection first manifests itself in the form of macules of the size of a pinhead or in patches of a somewhat larger area, the lesions varying in color according to their age and location, but always presenting a sharp contrast to the color of the adjacent normal integument. The younger lesions are vividly red over their entire surface or at their borders only, where a slight elevation above the general surface, due to hyperæmia and to the presence of a scanty desquamation, may be detected by the passing finger. The larger and older patches display varying shades of color ranging from a yellowish or light brownish tinge to deep orange, they are circular or rosette-shaped, or they have very irregular outlines. Vesiculation and papulation never occur and the only subjective symptom is possibly that of itching. It is the most chronic in its course of the dermatomycoses and lasts for months or years with but little change. Males are more frequently attacked than females; no case has been noted in childhood. Riehl's youngest case was sixteen years old, the oldest fifty-eight.

The fungus to which erythrasma is due was named by von Bärensprung the Microsporon minutissimum, the chief characteristics of which are the fineness of its threads and the minuteness of its spores. A power of six hundred diameters is required to make out the organism well. The threads present an inextricably interwoven mass with the spores scattered throughout in irregular clumps.

Erythrasma is chiefly to be distinguished from chromophytosis, but the different situations usually occupied by the former, its vivid coloring, and particularly the differences observed under the microscope are features sufficiently distinctive to enable one to make a positive diagnosis when in presence of one or the other affection. From chloasma, for which it might possibly be mistaken, it may be shown to differ by the ease with which erasion removes the superficial discolored epidermis.

The following simple plan of treatment will be found all-sufficient. After a preliminary hot bath, during which vigorous friction of the affected parts with scrubbing brush and soap has been maintained, a goodly proportion of the invaded epithelium will be found to have been removed, thus allowing a saturated solution of hyposulphite of sodium in water to do its work effectively. Afterward this solution should be dabbed on twice daily until the last trace of the parasite has been removed, for, as in chromophytosis, if this be neglected, even to the extent of overlooking so small a lesion as a pinpoint-sized macule, a starting-point will be left for reinvasion. Many other remedies are used. The list includes, sulphurous acid pure or dilute, a good remedy; a ten-per-cent. ammoniated mercury ointment; and ordinary sulphur ointment of the Pharmacopœia, to be well rubbed in. None of these, however, can be compared, as regards both cleanliness and effectiveness, with the hyposulphite of sodium treatment. *Charles Townshend Dade.*

ERYTHROPHLEUM, ERYTHROPHLEINE. See *Sassy Bark.*

ERYTHROXYLON. See *Coca.*

ESCHSCHOLTZIA.—A genus (fam. *Papaveraceæ*) of ten or more species, of the western and southwestern United States and of countries lying farther southward

Medicinal properties have been credited to the *E. Californica* Cham., but this was at a time when most of the species were included under that name, so it is not now known certainly to which species (one or more) these properties were said to belong. The plants are very showy and are widely cultivated for ornamental purposes. The herb contains chelerythrine (see *Celandine*) and at least one other alkaloid, and a glucoside. The presence of a small amount of morphine has been claimed, but this is probably not justified. Mild analgesic and soporific effects are obtained from the use of the extract in doses of about 1 gm., which may be increased to three or four times this amount. *Henry H. Rusby.*

ESPERANZA MINERAL SPRINGS.—Yates County, New York.

Post-Office.—Pen Yan.

Access.—By steamers on Lake Keuka or by a trolley line between Pen Yan, which is six miles distant in one direction, and Branchport, one mile distant in the other.

The springs are located at the head of the west branch of Lake Keuka, one of the most charming and picturesque of the many series of lakes which give the name of the lake section to this part of central New York. Lake Keuka is 700 feet above the ocean level, and within a mile of the springs an elevation of 1,100 feet higher may be reached. This is the great grape-producing section of New York, and the country about the lake is dotted on every hand with vineyards. Lovely walks, drives, and bicycle paths abound on all sides. The largest of the springs flows about one thousand gallons hourly. The water, which has a temperature of 51° F., has never been examined quantitatively. A qualitative analysis shows the following ingredients: Calcium carbonate, Calcium sulphate, Calcium phosphate, Calcium chloride, Magnesium chloride, Magnesium carbonate, Magnesium sulphate, Iron oxide (trace), Sulphuretted hydrogen gas, and Carbonic acid gas.

The water, when first taken from the spring, has both the taste and the smell of sulphur, but this disappears after a few hours, and the water becomes very palatable. There is no hotel at the springs, though there are many within easy reach. Lake Keuka is well supplied not only with hotels, but with cottages, steam yachts, sailboats, etc. No systematic effort has so far been made to put the Esperanza Spring waters on the market, although large quantities have already been sold.

James K. Crook.

ESTILL SPRINGS.—Estill County, Kentucky. These springs are located 40 miles west of Irvine. We are indebted to the United States Geological Reports for the following analysis, made by Dr. Robert Peter:

One United States Gallon Contains:[*]

Solids.	Red Sulphur Springs (near saloon). Grains.	Chalybeate Spring.[†] Grains.
Sodium carbonate	1.16	....
Calcium carbonate	11.66	9.32
Magnesium carbonate	4.64	2.93
Iron carbonate	....	1.75
Sodium sulphate	9.91	.58
Potassium sulphate	5.24	.58
Calcium sulphate	....	16.32
Magnesium sulphate	.58	9.91
Sodium chloride	5.24	.58
Alumina	....	Trace.
Silica	.58	1.75
Organic matter	2.33	8.16
Total	41.34	51.88
Gases.	**Cubic inches.**	**Cubic inches.**
Sulphureted hydrogen	0.26	....
Carbonic acid	18.98	15.68

[*] Converted from parts per 1,000.
[†] Alkaline calcic chalybeate.

The waters are principally of the light sulphuretted type, with one mild ferruginous spring. Another spring in the neighborhood, termed by Walton the "Irvine" Spring, is purgative, containing about 256 grains of sulphate of magnesium to the gallon. As far as we are able to learn, the place is not at present improved as a resort.

James K. Crook.

ETHER.—In medicine and pharmacy the word *ether*, unqualified, means, as it does in common parlance, the body *ethyl oxide* $(C_2H_5)_2O$, formerly, but improperly, called *sulphuric ether*. Ether is a product of reaction between sulphuric acid and alcohol, and is obtained by distilling a mixture of these two bodies, and purifying the distillate. Under the simple title *Æther*, Ether, the United States Pharmacopœia recognizes an ether of standard purity, "composed of about ninety-six per cent., by weight, of absolute ether, . . . and about four per cent. of alcohol containing a little water." This ether corresponds to what formerly was called *Æther Fortior*, Stronger Ether, a title abbreviated in the 1890 Pharmacopœia to the simple word "Ether."

Ether is "a transparent, colorless, mobile liquid, having a characteristic odor, and a burning and sweetish taste. Specific gravity: 0.725 to 0.728 at 15° C. (59° F.); or 0.714 to 0.717 at 25° C. (77° F.). Soluble in about ten times its volume of water at 15° C. (59° F.), with slight contraction of volume. Miscible, in all proportions, with alcohol, chloroform, benzin, benzol, fixed and volatile oils. Ether boils at about 37° C. (98.6° F.), and it should, therefore, boil when a test-tube, containing some broken glass and half filled with it, is held for some time in the hand. Ether is highly volatile and inflammable. Its vapor, when mixed with air and ignited, explodes violently" (U. S. P.).

Ether tends to decompose by prolonged keeping, developing, as one product, acetic acid. For use as an anæsthetic, ether ought to be pure and of standard strength. In all cases of suspicion, therefore, the surgeon should test his sample by the following simple procedures: 1. Let soak in the ether for ten minutes a piece of pale blue litmus paper, previously moistened with water; the paper should not redden, thus showing the ether to be free from acid. 2. Pour about two teaspoonfuls of the ether upon a piece of clean blotting-paper, free from smell, and let it evaporate; as the last of the ether is dissipated, no foreign odor should be perceptible on the paper, showing absence of impurities. 3. Saturate some water with the ether, and then shake together, in a graduated test-tube, 20 c.c. of such aqueous solution of ether with an equal bulk of the ether itself. Upon standing till the two fluids separate, the layer of ether should not measure less than 19.8 c.c., thus showing an absence of undue amount of alcohol or water—in other words, that the ether is up to standard in strength.

By reason of its extreme volatility ether is best kept in hermetically sealed tins. In bottles, whether cork- or glass-stoppered, leakage by evaporation is almost certain to occur, especially during transportation. Extreme inflammability is another property of ether requiring especial precautions in handling the fluid, and a point often overlooked is that air even moderately charged with ether vapor is explosive. Hence happens every now and then the ignition of an ether inhaler during anæsthetization by the leap of fire through intervening ether-charged air from a candle, or hot cauterizing iron, several feet removed.

Ether is a conjoint local irritant and constitutional narcotic. Being of high diffusion power, it is readily absorbed by living tissues, and so speedily declares its influence. Applied in full strength to the skin, and prevented from evaporating, it quickly reddens, and in time will blister. Absorbed into the blood, ether disturbs nerve function by attacking first and more profoundly the nerve centres, and secondly, and with less intensity, the nerves themselves. Of the nerve centres, the cerebrum seems to be the most sensitive to the ether influence, the disturbance being first a conjoint excitation of the emotional and blunting of the intellectual faculties, and finally an abrogation of all mental phenomena, and unconsciousness so absolute that upon awaking there is not even that vague appreciation of the duration of the narcosis that follows ordinary sleep. Next to the cerebrum suffers the sensory tract of the spinal cord, the affection being a progressive blunting of perceptivity, and next again the motor tract, suffering first by paresis and irritation, and finally by full paralysis. Lastly, the medulla oblongata becomes involved, its sensory centres, as in the case of the cord, succumbing first and its motor centres last. Upon the nerves ether has a paralyzing power similar to what it exerts upon the centres, but the influence is so feeble as to be producible only by direct application of ether to an exposed nerve. In impregnation of the blood with ether, death of the subject by paralysis of the medulla will take place before there is any obvious impairment of conductivity on the part of the nerve trunks. Of the great functions, *heart action* is stimulated by ether, the pulse of a healthy subject rising in force and frequency, and maintaining such quickened and deepened action even through a long and full narcosis. In profound etherization, however, the heart is weakened, but the effect is always insignificant as compared with the weakening wrought by chloroform, and in death by ether the heart is still irritable. *Arterial tension* is increased at first; in part, doubtless, as a result of the increased heart action, but in part also, apparently, by vaso-motor spasm. Later in the narcosis the blood pressure falls. *Respiration* is primarily stimulated, but secondarily depressed, until in full ether narcosis the breathing becomes slow and shallow; and, in case of overdosing, respiration is the function whose failure produces death. From the experiments of Knoll it would appear that these respiratory derangements are caused by direct action of the ether upon the respiratory centres. Functions presided over by the *sympathetic* nervous system are but little disturbed by ether. The *stomach* is easily upset by ether; full doses given by swallowing are repulsive and sickening; and after ether inhalation nausea and vomiting are common occurrences, especially if the narcosis has been of considerable duration, and especially, further, if an ether of inferior quality has been used.

Clinically, the effects of ether are as follows: In administration by the *stomach*, the medicine is so offensive that enough cannot be given to produce more than a moderate grade of the peculiar ether effect. Doses of from 4 to 8 c.c. (from fl. ʒ i. to ij.) can be swallowed, dissolved in a sufficiency of iced water, with the effect of stimulating the circulation and respiration, and producing mild exhilaration. Such a draught is powerfully reviving in conditions of heart failure or of depression of the vital powers generally, and also tends to steady the nervous system and to break spasm. Given by *inhalation of the vapor*, in as concentrated condition as possible, ether produces its full effect. Such inhalation is the common method of administration for the production of ether anæsthesia, and the attendant phenomena are as follows: *Subjectively*, if the attempt be made at the very start to breathe the vapor strongly concentrated, the pungency is intolerable; spasm of the larynx occurs, and despite all willingness to be etherized, the subject involuntarily gasps for breath and fights for release. Soon, however, the mucous membrane of the larynx becomes anæsthetized by the vapor, and then inhalation can proceed without distress. Following the cessation of laryngeal irritation come an indescribable thrilling and tingling throughout the body; a sense of physical lightness and mental exhilaration; a ringing in the ears, and exaggerated appreciation of sounds — phenomena that speedily give way to a consciousness of failure of cerebral power and command. Blunting of tactile sensibility is clearly appreciable, and, in the self-experience of the writer, a sensible interval—whether real or apparent only, it is, of course, impossible to say—occurs between the willing of a motor act and its execution. With ever-progressing rapidity, now, the grasp of the centre of consciousness upon the outer world through the nerves of sense slackens, until, following a whirl of mental confusion, even the consciousness of consciousness fails, and the next act of cerebrating is the realization of an awakening from a sleep of whose duration the subject has absolutely no conception or even suspicion. In a self-administration of ether in an absolutely quiet room at night, the writer, awakening from what seemed, and was intended to be, a momentary unconsciousness only, found to his utter amazement, on glancing at the clock, that *two hours* had elapsed since the beginning of the inhalation—two hours of a coma as dreamless and blank as that attendant upon a compression of the brain. After awakening from an ether narcosis there is more or less tendency to nausea, headache, and debility and wretchedness generally. *Objectively*, the phenomena are first a rise in the frequency and force of pulse and respiration, a suffusion of the face, and a tendency to emotional excitement, varying with the temperament and disposition of the subject, exactly as in the analogous condition of alcoholic drunkenness. So while the phlegmatic or the self-contained individual may sink quietly into coma, the excitable or the ungoverned subject may be outrageously jolly, or fearful, or pugnacious, or amorous, according to natural bent. At this period the proper test will show already a decided blunting of tactile sense and impairment of co-ordinating power. Speedily, next, the emotional displays grow feeble and incoherent, sweat starts out from the brow, the saliva flows, the face congests, the pupils contract, and the muscles at once both stiffen and tremble.

And, now, testing shows tactile perception to be abolished everywhere except in parts of high natural sensitiveness, such as the eye, the "quick" of the nails, and the ano-genital region. If the inhalation continue, the muscular rigidity and trembling give way, often with striking suddenness, to a condition of absolute paralysis and relaxation. At the same time the pulse falls somewhat, the respiration becomes slow and stertorous, the pupils dilate, all outward signs of conscious existence cease, and anæsthesia is absolute even in the most sensitive parts. While this condition lasts the face sweats freely, and the saliva flows in considerable quantities. Such a condition is the extreme to which narcosis should be pushed, since it represents an abrogation of all nerve action save that of the functions of organic life, and that determining the play of the heart and lungs. If the ether be pushed further the respirations become slower and shallower, the sphincters give way, and soon thereafter breathing stops altogether—the heart, however, continuing to beat for a short time still. On withdrawing the ether, sleep may follow, more or less prolonged, according to circumstances and according to the amount of ether consumed. Retching and vomiting may come next, often taking place quite suddenly and while sleep is still profound. On awakening, the subject is generally stupid and miserable, with co-ordination still deranged, and tactile sense blunted. Occasionally, but exceptionally, emotional excitement now appears, and in such cases there is sometimes a strong erotic excitation, with vivid illusions. Deceived by such experiences, female patients have been known honestly but falsely to charge the ether-giver or the operating surgeon with the taking of improper liberties, and even with rape.

Ether narcosis is a therapeutic measure for the production of *anæsthesia*, on the one hand, and of *muscular relaxation*, on the other. And the degree of the narcosis for either purpose will vary according to the circumstances of the case. In the line of anæsthesia, if it be for the relief of existing pain, a few whiffs of ether may suffice, without the production of narcosis at all, or it may be that the pain will yield only to the general unconsciousness of full coma. If it be for the abrogation of sensation during a surgical operation, the grade of narcosis necessary will depend upon the part to be attacked. In the case of all but the highly sensitive parts already enumerated, the ether effect need not be carried farther than the stage characterized by general muscular rigidity and trembling; but for operations on the very tender regions spoken of, the narcosis must be pushed to the stage of muscular relaxation and stertorous breathing. For the purpose of affecting motility, if it be for the breaking of a cramp or spasm, a few whiffs of ether are often all-sufficient, ether being indeed quite a potent antispasmodic; but if relaxation be sought for the easier reduction of a hernia or a dislocation, full narcosis to the stage of stertorous breathing will be necessary. The actual *quantity* of ether required for narcotizing by inhalation will vary according to the inhaler used, the skill of the administrator, the respiration, the condition of the stomach, whether full or empty of food, and, also, upon the habit of the subject in the use of narcotics, and even upon idiosyncrasy. With a good inhaler; with care to prevent waste by evaporation into the room; with a subject whose susceptibility is not impaired by habitual indulgence in either ether itself or in alcoholics, whose stomach is fairly empty, and who *will and can breathe with forced inspiration and expiration,* so small a quantity as from 20 to 40 c.c. (roughly, from fl. ℥ ss. to i.), may suffice to produce full unconsciousness. But, as conditions commonly obtain, far larger amounts are required, so that it is rarely safe to provide less than half a pound for an intended anæsthesia of even ordinary duration only.

For the production of constitutional effects, ether also can be administered by rectal injection of its vapor. This method was tested experimentally so long ago as 1847 by Pirogoff, of St. Petersburg, and was revived some years ago in association with the names of Axel Yversen, of Copenhagen, and Daniel Mollière, of Lyons—a revival to be followed by a new lease of deserved oblivion. Full narcosis can be produced in this way, and without respiratory distress, and perhaps also with less gastric derangement than by inhalation; but the procedure tends dangerously to irritate the intestines. Diarrhœa and bloody dejections have repeatedly followed the practice, with resulting death in at least two instances. In another case, death ensued from rupture of the intestine at the site of an old ulcer, through overdistention by the ether vapor.

The *practical administration* of ether to the development of narcosis is a special topic, treated of in this work in the articles on *Anæsthetics* and *Chloroform, etc.*, to which, therefore, the reader is referred. For ordinary medicinal purposes, ether may be administered by inhalation or by the stomach. If given by inhalation, a very little suffices, so that it is enough to direct that a teaspoonful of ether be poured upon a crumpled handkerchief, which handkerchief is then to be held directly against the mouth and nostrils, and the fumes inhaled during a few deep inspirations. In this prescription the precautions must be enjoined, first, that in case of self-administration the subject must lie down or sit so reclining or so braced that, in the event of unconsciousness, he will not fall to the floor; and, secondly, that the whole procedure shall take place at a distance of at least six feet from any exposed flame, such as that of a candle, lamp, gaslight, or open fire. By the stomach, from one to two teaspoonfuls is the average dose, best given in from eight to ten measures of ice-cold water, sweetened, if so preferred. Ether so taken is, however, a repulsive medicine, being offensive to the taste and tending to choke, because of its pungency. But, for internal giving, the common practice is to prescribe the pharmacopœial preparation entitled *Spiritus Ætheris Compositus*, Compound Spirit of Ether, or Hoffman's anodyne. This preparation is compounded of 325 parts, by measure, of ether, 650 parts of alcohol, and 25 parts of ethereal oil. It is a colorless volatile fluid, smelling and tasting of its three powerful ingredients. It forms a milky emulsion on admixture with water. It is used as an antispasmodic and general nervine and cardiac stimulant, and is given in average dose of from half a teaspoonful to one or two such measures, in water, plain or sweetened. In the United States Pharmacopœia there is also official a preparation entitled *Spiritus Ætheris*, Spirit of Ether, a preparation consisting of 325 parts, by measure, of ether, and 675 parts of alcohol in mutual solution. This spirit may be given as an internal medicine in doses of one [illegible] teaspoonfuls, administered in a goodly quantity of iced water, plain or sweetened.

A peculiar application of ether is the driving of the fluid, in atomized spray, upon the skin for the purpose of freezing that texture by the cold developed by the evaporation of the ether—such freezing being for the sake of the anæsthesia that attends it. In this application the ether is delivered from an atomizer of good capacity, the nozzle being held about an inch and a half from the skin. The first sensation, that of cold, is followed by a severe burning feeling, which in turn is succeeded, as the skin freezes, by loss of all sensation. When so frozen the skin appears pale, shrunken, and of tallowy hue and feel, and can be cut without pain. The effect is superficial only, and if a deep incision is to be practised, the tissues beneath the skin must, after section of that covering, themselves be frozen, before cutting, by a renewed application of the spray. Freezing by ether spray is quickly done, and, if not maintained beyond a short time, is not followed by any deleterious effect. The procedure is appropriate only for brief and superficial surgical operations, and often is more painful than the knife.

Edward Curtis.

ETHIDENE DICHLORIDE.—*Ethylidene Dichloride:* $C_2H_4Cl_2$. This is an ethereal body, isomeric with and much resembling ethylene dichloride. It has been experimented with as an anæsthetic, and has been found to operate after the general manner of chloroform, including the occasional killing of a subject. It is administered similarly to chloroform.

Edward Curtis.

ETHOXY-CAFFEINE ($C_8H_9N_4O_2.OC_2H_5$) is prepared by boiling three parts of monobrom-caffeine with two parts of caustic potash in ten parts of alcohol. It forms needles which melt at 140° C., are soluble in hot alcohol or cold hydrochloric acid; slightly soluble in water and ether, being less so than caffeine, and insoluble in alkalies. It is decomposed by hot acid, and even in water dissolves easily in the presence of sodium benzoate or salicylate. Filehne found that dizziness, dimmed intellect, and headache resulted from doses of seven to ten grains. Rabbits show narcotic and diuretic effects. The presence of the *ethoxy* group seems to add distinct hypnotic qualities to the diuretic power of caffeine, and the main use of the drug is as a sedative in nervous headache or migraine. Dose, gr. i. to v. (0.06–0.3 gm.).

W. A. Bastedo.

ETHYL BROMIDE.—*Hydrobromic Ether:* C_2H_5Br. This body is a thin, colorless, very volatile ether, of a strong smell and hot taste; practically non-inflammable; sparingly soluble in water, but freely so in alcohol and ether. It is prone to spontaneous decomposition, on exposure, and should be kept in dark-colored and well-stoppered bottles, away from the light. A yellowish tinge means decomposition, and a sample so discolored is unfit for use.

Hydrobromic ether affects the human system similarly to chloroform, with the special features that sensibility is deadened early, and that narcosis comes quickly and pleasantly, but without full muscular relaxation. The latter circumstance is a drawback, since often a continuing of rigidity and even of spasms into the stage of narcosis defeats the use of the agent as an anæsthetic in surgery.

Hydrobromic ether causes fall of blood pressure, and, in overdosage, death, all after the manner of chloroform. It has been used as an anæsthetic, given by inhalation of its vapor, especially in cases in which a momentary narcosis only is needed.

It is given similarly to chloroform.

Edward Curtis.

ETHYL CHLORIDE.—*Hydrochloric Ether:* C_3H_5Cl. Ethyl chloride is prepared by the action of hydrochloric acid on alcohol, the resulting ether being condensed at a low temperature. When maintained at a temperature below 50° F. it is a colorless liquid having an alliaceous taste and smell. Its specific gravity at 32° F. is .9214. It mixes with water, about one part in fifty, and with alcohol and ether in all proportions. Its boiling point is 50° F., and above this temperature it exists as a gas. As a gas it is exceedingly inflammable, burning with a greenish flame and evolving hydrochloric acid.

Following the introduction of ether and chloroform, it was one of the many compounds suggested as suitable for general anæsthesia. Being very volatile it was easily administered and its anæsthetic action was more rapidly procured. The anæsthesia which it produced, however, proved to be very transient, and further experience as well as experimental work has shown that its action is accompanied by marked vascular and cardiac depression. Although strongly advocated by many, its employment never became general and it has now fallen into disuse.

It is now better known as a local anæsthetic. Advantage has been taken of its rapid evaporation to utilize the intense cold produced, in dental and minor surgical practice, and for the relief of the pain of superficial neuralgia. It has been used with satisfaction for the extraction of teeth, for opening abscesses, for removing ingrowing toenails, and for similar painful operations, and has been found to give instantaneous relief in facial neuralgia, intercostal neuralgia, and sciatica.

The method of utilizing this property was made simple and easy by M. Mounet, of Lyons, who suggested the storing of the compressed fluid in small capsules and tubes, by which means it may be preserved without alteration for a great length of time. When the drug was required for use the point of the capillary tube was broken off, and the opening directed downward on the part to be anæsthetized. These tubes have now been perfected by the addition of a screw cap which allows of any proportion of the contents being utilized, the remainder being preserved for future use. The heat of the hand is sufficient to raise the temperature of the fluid above its boiling point, and a stream of the rapidly volatilizing fluid issues as a spray, and may be applied to any part. The tube should be held at a distance of eight or ten inches from the part, and the surrounding tissues protected to prevent excessive and needless destruction of tissue. The surface of the skin acted upon rapidly becomes blanched and devoid of sensation, and regains its normal state upon the removal of the spray. If the application is persisted in, the vitality of the part is destroyed and necrosis is the result. During the employment of the spray care must be taken that no flame shall be in proximity, on account of the inflammability of the gas.

Beaumont Small.

ETHYL FORMATE.—*Formic Ether:* $H.COOC_2H_5$. This is the ethyl ester of formic acid, and is an ethereal liquid smelling like peach kernels. It is soluble in ten parts of water, and boils at 54° C. It is said to be of value as an antiseptic to the upper air passages.

W. A. Bastedo.

ETHYL IODIDE.—*Hydriodic Ether:* C_2H_5I. This body is a colorless ethereal fluid, non-inflammable, practically insoluble in water, but freely soluble in alcohol. It has a sharp taste and a smell simply penetrating if pure, but if impure often offensive. Ethyl iodide affects the human system after the manner of the volatile ethers generally, but is used in medicine—so far as it is used at all—either for the sake of *iodizing*, for which purpose some consider it efficacious, or for relieving oppression of breathing in pulmonary complaints. It is administered by inhalation, in dosage of fifteen drops.

Edward Curtis.

ETHYL PHENACETIN ($C_6H_4.OC_2H_5.NC_2H_5.CH_3CO$) is prepared by the action of ethyl iodide on phenacetin sodium. It is a yellow-colored oil, almost insoluble in water, readily soluble in alcohol and ether, and boiling at 350° C. As was expected, the introduction into phenacetin of an additional ethyl group has increased its hypnotic tendency, but the drug is not of sufficient value to be classed with such hypnotics as trional, chloralamide, etc.

W. A. Bastedo.

ETHYLENE BROMIDE.—$C_2H_4Br_2$. This organic compound was introduced into therapeutics as a convenient means of supplying bromine in cases in which its use is indicated for a prolonged period. The advantage claimed for it is, that it is not combined with potassium, sodium, or any basilous radicle, and its use does not disturb the digestion, the skin, or the mucous membranes, or produce any of the unpleasant effects that the older salts are liable to cause.

It is a colorless or faintly brown liquid, containing 90.9 per cent. of bromine. The odor is agreeable and taste sweetish. Its specific gravity is 2.163 at 69.8° F. Below 48° F. it becomes a solid, forming crystals. It is insoluble in water, soluble 1 in 4 of rectified spirit, and miscible in all proportions with absolute alcohol and oils.

The employment of ethylene bromide in epilepsy was recommended by Dr. J. Donath.[1] He used it in a great number of cases, and reports the details of ten cases in which he was able to watch its effects carefully. As a substitute for the bromides he found it very satisfactory, and the results, in his estimation, were much better. The cases were all of long standing and had been subjected to many forms of treatment. Under the use of the remedy the attacks became milder, shorter, and fewer in number, and in many instances assumed the character of *petit mal.* In three of the cases the convulsions were replaced by simple muscular twitchings without loss of consciousness.

The dose administered was gtt. vi. to xij. three times a day. It may be given in capsules with oil or in solution. The following preparations are recommended: (1) Ethylene bromide, gr. lxxv.; oil of almonds emulsion, ℥ iij.; oil of peppermint, gtt. ij.; dose, gtt. xxx. three times a day, in a third of a glass of milk. (2) Ethylene bromide, gr. xxiv.; rectified spirits, gr. lxxv.; oil of peppermint, gtt. ii.; dose, gtt. v. to x. three times a day. In preparing these mixtures the high specific gravity must not be forgotten, it being nearly two and a half times as heavy as water. Before using the drug Donath tested its action on himself, and found that in ordinary doses it did not produce any disturbing effects; but in large doses it was sometimes followed by nausea.

This drug must not be mistaken for ethyl bromide, which it resembles both in name and in appearance. A case is reported[2] in which such a mistake was made with fatal consequences. A written order for the anæsthetic, ethyl bromide, was sent to a druggist, who supplied ethylene bromide. Ten drachms were inhaled without producing any insensibility or anæsthesia. The administration was followed by suppression of urine and uncontrollable vomiting, which continued until the patient died, upon the following day. At the post-mortem examination there was found an hyperæmia of the meninges of the brain, also of the lungs, spleen, and kidneys. The liver was much enlarged, of a dirty-yellow color, and the cells were affected by a granular degeneration.

Beaumont Small.

ETHYLENE-DIAMINE [$C_2H_4(NH_2)_2$] is a clear, colorless liquid of specific gravity 0.970. It is readily soluble in water, has an ammoniacal odor, and strongly alkaline reaction, and dissolves albumin easily. It has been recommended for the solution of the false membrane of diphtheria, being especially useful, as its efficiency is not destroyed by antiseptics.

Ethylene-diamine-trikresol or *trikresolamine* is a solution of two per cent. each of ethylene-diamine and trikresol. It is a clear colorless liquid of alkaline reaction, becoming slightly yellow and cloudy on exposure to air. On account of this cloudiness, the manufacturers now make

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[1] British Medical Journal, July 11th, 1891.
[2] The London Lancet, January 10th, 1891.

kresamin, a twenty-five-per-cent. solution of these two chemicals from which a one- or two-per-cent. solution may be prepared when wanted (see *Kresamin*).

Ethylene-diamine silver phosphate is argentamine (see *Silver*).
W. A. Bastedo.

ETHYLENE DICHLORIDE. — *Ethene Dichloride, Dutch Liquid:* $C_2H_4Cl_2$. This body is a thin, colorless, oily fluid, smelling and tasting much like chloroform; volatile and inflammable; dissolving sparingly in water and freely in alcohol and ether. Its only medical interest lies in its attempted substitution for chloroform, as an anæsthetic which should retain the advantages of chloroform while free from its dangers. It seems to operate much like chloroform, and, according to Reichert, has little tendency to paralyze the heart. It is, however, very irritating to the throat. Administration, in mode and dose, is the same as with chloroform.
Edward Curtis.

ETHYLENE-PHENYLHYDRAZIN-SUCCINIC ACID ($C_{20}H_{22}N_4O_6$) is prepared by boiling ethylene-phenylhydrazin with succinic anhydride in alcohol. It forms crystalline needles soluble in water, and is used as an antipyretic.
W. A. Bastedo.

ETHYLIDENE CHLORIDE (CH_3CHCl_2).—Chlor-ethylidene; chloriden; ethidene bichloride; Aran's ether; Wigger's ether. This is a colorless ethereal liquid prepared by the action of chlorine on ethyl chloride. It has an agreeable fruity odor, a boiling point of 57° C. (134.6° F.), and specific gravity 1.180. It has been used as a safe and ephemeral general anæsthetic for short operations.
W. A. Bastedo.

ETIOLOGY. See *Infectious Diseases.*

EUCALYPTUS.—Blue Gum-tree. "The leaves of *Eucalyptus globulus* Labillardière (fam. *Myrtaceæ*) collected from the older parts of the tree" (U. S. P.). At the close of this article will be found some general information concerning the genus Eucalyptus. Attention is here restricted to the drug above-defined. This species occurs in the province of Victoria, Australia, and in Tasmania. It grows to a great size, but is not nearly so large as some of the other species. The exhalations from the tree, where forests of it occur, and especially from the fallen leaves, charge the atmosphere, thereby disinfecting it. This has suggested the idea of planting it in malarial regions, as about Rome, for a similar purpose, but it is doubtful if the experiment has anywhere been performed in a sufficiently thorough manner or upon a sufficiently extensive scale. It was an incorrect notion of this property of the tree which suggested its first use in medicine, that of a specific for malaria. In this direction it proved disappointing, but other important medicinal uses were found for it. The tree, when young, and the younger portions of it for some time after, bear leaves which to a great extent are wanting in the active constituent. These leaves are broadly ovate, heart-shaped at the base, little or not at all tapering at the apex, and comparatively thin. The official leaves (Fig. 1944) are 15 to 30 cm. (6 to 12 in.) long by 2 to 4 cm. ($\frac{3}{4}$ to $1\frac{1}{2}$ in.) broad, lanceolate and tapering from near the blunt base to an acute tip, strongly scythe-shaped, and very inequilateral, entire-margined, very thick, leathery, smooth, strongly glaucous, and with a short, stout, flattened and twisted petiole. Against the light they are strongly pellucid-punctate. They are highly aromatic. It is not known how leaves grown in the several countries where the tree has been introduced compare with those of native origin, but some of them are known to be very inferior, and it is certainly a conservative and wise policy to accept only those of native growth.

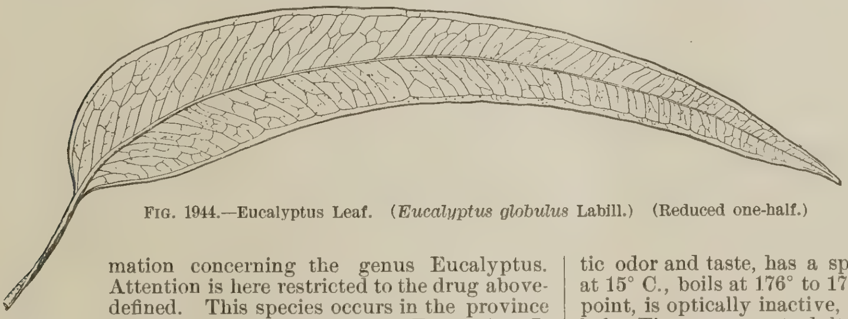

FIG. 1944.—Eucalyptus Leaf. (*Eucalyptus globulus* Labill.) (Reduced one-half.)

COMPOSITION.—Besides their active constituent, about six per cent. of volatile oil, they contain wax, resin, and tannin. The medicinal properties and uses of the drug can be best considered farther on, in connection with those of the oil and of eucalyptol.

Oil of Eucalyptus (*Oleum Eucalypti*, U. S. P.) is defined as "a volatile oil distilled from the fresh leaves of *E. globulus* Labillardière, *E. oleosa* F. von Müller, and some other species." It has a specific gravity of about 0.915 to 0.925 at 15° C., a characteristic odor and taste, and it dissolves freely in alcohol. Since the active constituent of the oil is *eucalyptol* (properly called cineol), the determination of the percentage of that constituent constitutes the proper method of valuation. For the same reason, it seems more rational for the Pharmacopœia to drop the oil from its next edition and to specify only the eucalyptol. With eucalyptol, there is pinene (from *E. globulus*) or cuminol (from *E. oleosa*), or the two oils may be mixed. Traces of several aldehydes may also be present. The optical rotation will also differ greatly in accordance with the source. The definition is faulty in that it does not specify the "other species," the oils of some of which are very distinct, even to being quite wanting in eucalyptol. The action of the oil, except for its being weaker and less regular, is that of eucalyptol. Phellandrene is its most common impurity, derived from other species of Eucalyptus.

Eucalyptol or *Cineol* ($C_{10}H_{18}O$) is defined by the Pharmacopœia as "a neutral body obtained from the volatile oil of *Eucalyptus globulus* Labillardière and of some other species of eucalyptus." The allowance of "other species" is here not objectionable as in the case of the oil, for the eucalyptol will be the same no matter what its source. It is also the active constituent of oil of cajuput and of some other Myrtaceous oils, and occurs in santonica, rosemary, peppermint, and many other oils of this and of other families. It is liquid, colorless, with a characteristic odor and taste, has a specific gravity of about 0.930 at 15° C., boils at 176° to 177° C., crystallizes at freezing point, is optically inactive, and dissolves freely in alcohol. The commonest adulterant is the oil, which at once renders it optically active.

ACTION AND USES.—The action and uses of eucalyptol and of the oil must be considered first, as that of the leaves is not quite identical. Their special property among volatile oils (see *Active Constituents of Plants*) is their antiseptic and expectorant properties. As an antiseptic, eucalyptol ranks second only to oil of cinnamon, and this property increases somewhat as the oil ages. It is not markedly irritating to the skin unless the surface is abraded or the vapor is confined, but it is markedly irritating to mucous membranes, especially to that of the stomach. As an expectorant, whether taken internally or by inhalation, it is both stimulating and antiseptic. Its antiperiodic action is very similar in kind, but also very inferior, to that of quinine. As a poison it acts as a gastro-intestinal irritant, and as a paralyzant of the vital functions, especially of the heart.

The uses of this drug are all to be regarded as local; even when given internally, it is transported in the circulation to the seat of its action. Externally, it is an excellent application to ulcers which require either disinfection or stimulation. For this purpose, a two- to five-per-cent. solution of the oil in alcohol may be employed, or a ten-per-cent. tincture of the leaves is sometimes even better, owing to the resin and tannin contained. The greatest value of eucalyptus is in the treatment of catarrhal conditions. Here the beneficial results are directly proportional to the need for stimulation and disinfection, and the reverse is true when there is already irritation or inflammation. Thus it is used topically, as well as internally, in gonorrhœa and vesical catarrh, in low forms of dyspepsia, and in respiratory catarrh. Although slightly diaphoretic, it is scarcely useful in that way. Its antiperiodic powers are feeble, but it is often of use when the case is mild, and the surroundings are not continuously infectious.

In considering the properties of the leaves, we have to regard only the percentage of oil which they contain, and the fact that the amounts of resin and tannin, and the bitter taste, are sufficient to add their effects to those of the eucalyptol.

The dose of the leaves and of their fluid extract, the only official preparation, is 2 to 8 gm., or c.c. (ʒ ss.–ij.), respectively. The oil and the eucalyptol are given in doses of from 0.3 to 2 c.c. (♏v. to xxx.).

The genus Eucalyptus contains between one hundred and twenty-five and one hundred and fifty species, almost all of Australia and Tasmania. They are for the most part large trees, rivalling in altitude the highest known, and form dense and vast forests. Their economic importance is of the highest. Their ability to withstand adverse climatic conditions permits of forestry operations where they would be otherwise impossible. Their timber is proof against the attacks of many destructive animals, and resists decay. Their astringent gums, described below, are of great importance. Many of the oils, though excluded from the uses above specified, as they contain no eucalyptol, are of importance in the arts. The trees are, moreover, highly ornamental.

(See *Honey*, *Eucalyptus*, and *Manna*, *Australian*).

Henry H. Rusby.

EUCALYPTUS GUM.—Eucalypti Gummi. A ruby-colored exudation, or so-called red gum, from the bark of *Eucalyptus rostratus* Schlecht, and some other species of eucalyptus. Sixteen species of eucalyptus have been named as yielding these gums, which are now very generally used in the place of our official malabar kino, this having become excessively scarce and high-priced. It is even true that the former is very commonly given when the latter is called for. The two are very similar indeed, this one occurring in grains or small masses, the fragments transparent and of a ruby-red or garnet-red color, somewhat tough and of a very astringent taste. When chewed, it adheres to the teeth and tinges the saliva red. Cold water dissolves from eighty to ninety per cent., forming a neutral solution, and it is almost entirely soluble in ninety-per-cent. alcohol. The properties and uses of this substance are identical with those of kino, and the dose is gr. ij.–v. *Henry H. Rusby.*

EUDERMOL, or nicotine salicylate, occurs in colorless hexagonal crystals or anhydrous needles, melting at 117.5° C., and soluble in water, alcohol, and oils. It contains fifty-four per cent. of nicotine, is non-irritant, odorless, and does not soil the clothing, and in 0.1 to 0.25 per cent. ointment is recommended in scabies, sycosis, and other parasitic skin diseases. Applied to a raw surface, it may produce symptoms of nicotine poisoning.

W. A. Bastedo.

EUGALLOL, or pyrogallol monoacetate [$C_6H_2.CH_3\text{-}CO.(OH)_3$], is a thick, brownish, transparent, syrupy material, readily soluble in water and in its own weight of acetone. It is marketed in thirty-three-per-cent. acetone solution, and when this is painted on the skin and allowed to evaporate it leaves a firm, elastic varnish. It is used in skin diseases, and Kromayer claims that when applied every day it induces an inflammation under whose influence the most stubborn psoriatic patch will disappear. He adds to its usefulness by dusting it with zinc oxide before it is dry. *W. A. Bastedo.*

EUGENOFORM is the sodium salt of eugenol-carbinol, the product of the action of formaldehyde on eugenol. It forms broad, colorless crystals, readily soluble in water, with difficulty in alcohol, and insoluble in ether. Its melting point is 160° C. The claim is made that it liberates formaldehyde in the system, and on this account Vogel recommends it as antiseptic to the gastro-intestinal tract in cholera, typhoid, etc. Its dose is 0.5–1 gm. (gr. vij.–xv.). *W. A. Bastedo.*

EUGENOL; EUGENIC ACID. See *Cloves.*

EUGENOL-ACETAMID ($C_6H_3.C_3H_5.OCH_3.OCH_2.CONH_2$) is prepared by the action of eugenol sodium on monochloracetic acid, with subsequent heating in the presence of ammonia. It forms fine needles or plates, and, according to Merck, is a local anæsthetic and antiseptic. It can be used for toothache or neuralgic pains.

W. A. Bastedo.

EUGENOL IODIDE, or iodo-eugenol ($C_6H_2I.C_3H_5.OCH_3.OH$), is obtained by the action of iodine on eugenol sodium. It is a yellowish, odorless, insoluble powder, which melts at 150° C. (302° F.), and is used as an antiseptic or as an iodoform substitute. *W. A. Bastedo.*

EUNATROL is a proprietary pill of sodium oleate coated with chocolate. Extravagant claims are made as to its value in gall stones and other biliary derangements. Dose, 1 gm. (gr. xv.) three times a day.

W. A. Bastedo.

EUNOL exists in "alpha" and "beta" modifications, made by combining eucalyptol with alpha- and beta-naphthol, respectively. These compounds are bitter, insoluble in water, and soluble in alcohol, ether, chloroform, and oils. They are antiseptic, and may be used in surgery and dermatology. *W. A. Bastedo.*

EUONYMUS; EUONYMIN. See *Wahoo.*

EUPATORIUM. See *Thoroughwort.*

EUPHORBIA PILULIFERA L.—A plant of the order *Euphorbiaceæ*, which has been recommended as a remedy for spasmodic affections and neuroses of the respiratory tract. It is indigenous to Australia, Brazil, and other Southern tropical countries. It derives its specific name from the seeds, which are held in capsules in the axils of the leaf, and when ripe are brown and hard. It is commonly known as the pill-bearing spurge. It is a very common annual herbaceous plant, and has a local reputation as a curative agent in all pulmonary troubles. Dr. Mattheson, of Queensland, was the first to call attention to its value in asthma, paroxysmal dyspnœa, whooping-cough, and other spasmodic affections. Later, it was studied by Dr. Marsset, under the direction of Dujardin-Beaumetz, and the result of his researches was published in the *Therapeutic Gazette*, February, 1885. Its action is directed to the respiratory and cardiac centres, and causes a retardation of the respiration and pulse, and when death has been produced it arises from a paralysis of these organs. It does not influence any of the other organs of the body, but when administered in excess it produces an irritant action on the gastric mucous membrane.

Its active principle is an acrid resin, which is soluble in water and dilute alcohol. Experiments on animals show that one part of the resin to one hundred of the animal, by weight, will produce a fatal result.

It has proved of service in all spasmodic affections of the bronchial tubes and lungs, in the dyspnœa of emphysema of the lungs, and in that due to cardiac affections. Dujardin-Beaumetz recommends it to be used in all cases in which iodide of potassium is used to relieve dyspnœa.

It has also been used to relieve the spasms and distress of angina pectoris, and in hay asthma as well as in coryza. In the latter diseases it rapidly checked the sneezing and other troublesome symptoms.

The dried plant is used, and its virtues are said to be best extracted by water. A decoction may be made by steeping half an ounce of the plant in two quarts of water, the dose to be three or four wineglassfuls during the day. The fluid extract is the best preparation to use, the dose being from fl. ʒ ss. to i. *Beaumont Small.*

EUPHORBIACEÆ.—(*The Spurge Family.*) One of the most important medicinal families of plants, if we consider its domestic as well as its professional uses. It contains more than two hundred genera and three thousand species, distributed over almost the entire earth, most abundant in the tropics, gradually decreasing with the temperature, and wanting in very cold regions. Their most notable property is their great power of adaptation to environment, so that some of them thrive equally well in the most arid deserts, and amidst luxuriant floras. Their economic value is great in other than medicinal directions. Two of our best rubbers are yielded respectively by the manihot and the heveas. Other manihots yield the highly important food cassava and its starch, tapioca. Some of the fruits are edible, and some of the timbers have special uses. Numerous species yield useful fixed oils, and several dye-stuffs are obtained. Medicinally, the properties depend almost entirely upon local stimulation or irritation, even the "alterative" effects probably depending ultimately upon some such depurative action. This irritating action increases in many species to the point of rendering them violent poisons, either externally or internally, or both. These irritating principles exist commonly in the milky juices with which the tissues abound, these being frequently highly caustic to the skin or other tissues. Even such violently acting juices have often been utilized as escharotics or epispastics. Among such juices we may mention those of *Hura*, *Euphorbia heterodoxa* Muell (Alvelos), and other species of this genus, *Hippomane, Toxicodendron, Ophthalmablapton*, and *Excoecaria*. The latter acts violently even by access of its smoke, and smoking the body with it is, among the Fiji, a heroic treatment for leprosy. Juices, mostly milder in their action, are used internally as irritant purges, but many of them in overdoses may prove emetico-cathartic poisons. Rarely do these purgatives consist of the extracted juice, as in *euphorbium*, but usually of the tissues containing the latex, fresh or dried, or medicinal preparations of them. Among such may be mentioned the root of *Jatropha macrorhiza* Benth., of *Stillingia*, of *Euphorbia Ipecacuanhæ* L., *E. Lathyris* L., *E. marginata* Pursh., *E. corollata* L., *E. Cyparissias* L., and other species of this genus, the spurges, the herbage of *Mercurialis*, *Tragia* sps., and *Joannesia*, and various parts of many species of *Croton* and *Phyllanthus*. Many of the latter are also used as fish poisons. In other cases, the purgative constituent is, or resides in, a fixed oil, usually of the seeds, as in croton, castor, and curcas oils. Powerful albuminous poisons usually also reside in these seeds. Occasionally, as in buxus, alkaloids occur, while a number of special or exceptional drugs, like kamala and cascarilla, will be found discussed in their proper alphabetical order. A complete enumeration of the medicinal species of the family would fill several of these pages.

Henry H. Rusby.

EUPHORBIUM, Ph. G.—An irritating and drastic gum resin, obtained from *Euphorbia resinifera* Berg (fam. *Euphorbiaceæ*). This is a large, leafless, cactus-like perennial, growing from four to six feet high, having a thick, gray, woody stem, and numerous very fleshy, quadrangular, spiny green branches. The plant is laden with a milky juice, which exudes when it is wounded, and dries readily in tears upon the surface or entangled among the spines. It is a native of the interior of Morocco.

The resin is exported from Mogador. It has been known in European commerce from a very remote period, is mentioned by numerous older medical writers, and had its place in most pharmacopœias, but its use is now nearly obsolete. It is collected by incising the stems early in the season, and collecting the hardened tears some weeks later. These are usually irregular, from the size of a hickory nut down, yellow, translucent, with a dull, waxy surface, and a brittle fracture. They often enclose or fasten spines or other portions of the plant. Frequently they are perforated. The odor is slight, unless heated, but the dust raised by gathering, sorting, or powdering it is exceedingly irritating to face and nose, so that those handling it should wear veils, or take means to avoid the dust. Flückiger's analysis of euphorbium gives it the following composition: *amorphous resin*, 38; *euphorbon*, 22; *mucilage*, 18; *malates*, 12; *inorganic ingredients*, 10. Of these, the irritating and active principle is the amorphous resin. It is soluble in alcohol.

Action and Use.—Euphorbium is a violent irritant, like cashew nuts, chrysarobin, croton oil, etc.; it is also, like the latter, an irritant drastic. Formerly it was used internally for this quality, but is now never so given. For external use as an irritant, or, more generally, diluted with other things, as a rubefacient (ointments, plasters, etc.), it is occasionally called for, and in the more obstinate chronic skin affections has some value; but the necessity which cannot better be met with other medicines must be rare. *W. P. Bolles.*

EUPHORIN.—Phenyl-urethane. Carbonate of ethyl and phenyl. This is a compound derived from aniline and is somewhat allied to acetanilid. It occurs as a white crystalline powder, with a faint aromatic odor and slight taste, almost insoluble in water, but freely soluble in weak alcohol and wines. It was introduced by Dr. Sansoni * to replace antipyrin, antifebrin, and other drugs of the same class. The dose is from gr. viiss. to xv.

It is also employed as an antiseptic powder in the treatment of ulcers and wounds. *Beaumont Small.*

EUPHTHALMIN HYDROCHLORATE ($C_{17}H_{25}NO_3$.-HCl).—The mandelic acid derivative of labile n-methyl-vinyl-diacetone-alkamine, was introduced to ophthalmology by Treutler in 1897. It is closely related to beta-eucaine, the hydrochlorate of benzoyl-vinyl-diacetone-alkamine, bearing to this the same relation as does homatropine to tropacocaine. It is a white, crystalline powder, readily soluble in water and in two parts of boiling alcohol, but separating into crystalline aggregates on addition of ether. It is anhydrous, melts at 183° C., and is not decomposed by boiling.

The salicylate ($C_{17}H_{25}NO_3.C_6H_4.OH.COOH$) is made by dissolving equal parts of euphthalmin (base) and acid salicylic in absolute ether, and recrystallizing from ether and alcohol. It melts at 115° C., and is readily soluble in water.

Experiments on animals by Vinci show a primary irritation of the nervous system in the form of restlessness, excitement, and increased reflexes, then tonic and clonic spasms, opisthotonos, exophthalmos, cyanosis, disturbed respiration, and death from general paralysis. The vaso-motor system is directly paralyzed, and blood pressure falls in spite of increased cardiac activity. Instilled into the eye in one- to ten-per-cent. solution, it produces salivation from its action on the secretory fibres of the chorda tympani; and, owing to paralysis of the nerves of the sphincter iridis, without affecting the sympathetic dilator fibres, mydriasis supervenes in fifteen to forty minutes, to disappear practically in two to eight hours, and completely in less than twenty-four hours. It also dilates the pupil when given internally.

Hinshelwood obtained the maximum dilatation from three separate drops of a five-per-cent. solution at two-minute intervals, this acting somewhat less promptly in one eye, than one-per-cent. homatropine solution in the other eye of the same patient. Euphthalmin acts more rapidly in young than in old people, causes no smarting or discomfort, weakens accommodation but little, has no appreciable effect on the conjunctival vessels or the corneal epithelium, and increases intra-ocular tension but slightly or not at all. The mydriasis is more complete in strong sunlight than that of cocaine or homatropine, yet there is such slight effect on accommodation that reading and writing are not materially interfered with. Jackson found no case in which the pupil was entirely without response to light, and noted that during the maximum effect about one-fourth of the total accommodation was lost. He prefers cocaine for ordinary ophthalmoscopic work, using euphthalmin for testing vision with strong light in cataract, or as a rapid mydriatic where iritis is suspected but still uncertain. He recommends a solution containing one per cent. each of euphthalmin and cocaine hydrochlorates. Knapp uses a ten-per-cent. solution for ordinary ophthalmoscopic examinations, stating, however, that it dilates the pupil less powerfully than atropine. Sneguiroff increased the speed of its action by a prior instillation of one per cent. holocain, this hastening the diffusion of fluids from the conjunctival sac into the anterior chamber. Some observers have used euphthalmin in glaucoma, claiming that its brief mydriasis does not allow of increased tension, yet its safety in this condition has not been proven. In glaucoma and in the aged, cocaine is a more suitable agent. As yet toxic effects from the drug have not been reported. Euphthalmin will act in one-per-cent. solution, but it requires repeated instillations to produce mydriasis.

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* Therap. Monatsh., November, 1890.

W. A. Bastedo.

EUPYRIN.—Vanillin-ethyl-carbonate-p-phenetidin. This substance belongs to the paraphenetidin group which includes phenacetin, being a compound of paraphenetidin with vanillin. It forms pale, greenish-yellow needles of vanilla-like odor and without taste. It is freely soluble in alcohol, ether, and chloroform, but with difficulty in water. This is an antipyretic, which, according to Overbach, possesses stimulating properties, as evidenced by the sensation of well-being which follows its ingestion. It is of no use in neuralgia, but is recommended as a mild, non-toxic antipyretic, especially suitable for old people or children, or in cases of fever with great weakness. *W. A. Bastedo.*

EUQUININE, or Quinine-carbonic-ether $(CO.OC_2H_5.OC_{20}H_{23}N_2O)$, is the ethyl carbonic ester of quinine produced by the action of quinine on ethyl carbonyl chloride. It forms white needle-like crystals in fleecy masses which melt at 95° C. Its reaction is alkaline, and its taste flat with a slightly bitterish after-taste. It dissolves with difficulty in water, but readily in alcohol, ether, chloroform, and dilute acids, the acid solutions fluorescing like those of other quinine compounds. The hydrochlorate is the most soluble salt, the sulphate slightly soluble, and the tannate almost insoluble. Euquinine gives the thalleoquin reaction, but not the herapathite reaction of quinine.

Euquinine is a quinine compound which clinical reports show to possess all the valuable properties of the mother substance, without causing, in therapeutic dosage, ringing of the ears, nausea, headache, or other symptoms of cinchonism. As it is also practically tasteless, it can be administered to children with ease. It is said also to be borne well by those having an idiosyncrasy against quinine. Bernheim uses it in solution with ferric chloride for lavage in gastritis with dilatation, and as an enema in the stubborn diarrhœa of colitis. Goliner prefers it to quinine, acetanilid, antipyrin, or phenacetin in la grippe. For malaria it is best preceded by a mercurial laxative and combined with ginger or other aromatic. It is highly recommended in whooping-cough and the fevers of phthisis. The dose up to 2 or 3 gm. (gr. xxx.–xlv.) is slightly larger than that of quinine sulphate, and it can be administered in soup, gruel, milk, cocoa, or flavored syrup. *W. A. Bastedo.*

EUREKA SPRINGS.—Carroll County, Arkansas.

Post-Office.—Eureka Springs. Hotels: Crescent and Southern, and numerous smaller houses.

Access.—Viâ Eureka Springs, branch of the St. Louis and San Francisco Railroad.

The development of Eureka Springs affords a forcible object-lesson of the progress of civilization in the Western wilds of America. Where a few years ago was an uninhabited sterile mountain glen, now nestles a bright little city of more than 6,000 inhabitants, which number is greatly increased by the large floating population of visitors, tourists, business men, and invalids constantly coming and going. The city is lighted by gas and electricity, contains an electric railway system, and excellent schools, hotels, etc. The Interstate Summer Normal and Educational Assembly have erected a building with a seating capacity of five thousand persons, in which annual summer sessions are held and attended by visitors from all parts of the Union. The State District Normal School of Arkansas is also located here. The springs are sixty in number, the best known being as follows: The "Crescent," "Dairy," "Basin," "Magnetic," "Harding," "Little Eureka," "Sweet," "Grotto," "Mystic," "Oil," "Arsenic," "Cave," and "Cold" springs. The waters contain mainly carbonates of lime and magnesia, with a small proportion of sulphates and chlorides. They are not strongly mineralized, and differ but slightly from each other. The following table from the report of F. W. Clarke, Chief of Division of Chemistry, United States Geological Survey, and R. R. Riggs,* shows the proportion of solids in four of the principal springs:

	Grains per United States gallon.
Crescent Spring	5.36
Dairy Spring	6.29
Basin Spring	6.97
Magnetic Spring	10.99

The following table sent us by Dr. John D. Jordan, of Eureka Springs, shows some of the climatic advantages of the resort:

Eureka Springs.	Altitude above sea level		2,000 ft.
	Annual average precipitation		32.79 in.
	Mean temperature (Fahr.)	Spring	60.85°
		Summer	74.79°
		Autumn	58.01°
		Winter	42.08°
	Annual average		58.93°
	Relative humidity (per cent.)		58.93
	Average number of days per annum	Clear weather	209
		Fair weather	90
		Cloudy weather.	66
	Death rate per annum		10.33 per 1,000

The city is picturesquely located on the headwaters of the White River in the Ozark Mountains. A sojourn at Eureka Springs and the free use of its waters are stated to be beneficial in a wide range of affections, including rheumatism, skin, nervous, renal and bladder disorders, dyspepsia, hay fever, and general debility.

James K. Crook.

EUREKA SPRINGS.—Humboldt County, California.

Post-Office.—Eureka.

These springs are located near the town of Eureka. The waters belong to the muriated-sulphureted class, and were analyzed by Prof. W. D. Johnson in 1885, with the following result:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	1,403.00
Sodium carbonate	10.10
Sodium bromide	14.00
Potassium sulphate	12.20
Magnesium chloride	101.00
Magnesium sulphate	211.30
Calcium carbonate	3.80
Calcium sulphate	42.50
Alumina	1.30
Silica	.95
Ferrous carbonate	.12

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* February 15th, 1877.

Solids.	Grains.
Manganese	Trace.
Boric acid	Trace.
Iodine	Trace.
Lithium	Trace.
Total	1800.27
Carbonic acid gas	Small amount.
Sulphureted hydrogen	Saturated.

This water is now used extensively by the residents of the neighboring districts. It is also shipped to San Francisco. The action of the water is laxative and diuretic. *James K. Crook.*

EURESOL, or resorcin monoacetate [$C_6H_3(OH)_2.CH_3CO$], is a viscid, transparent mass of pleasant odor, and easily reduced to a powder. Kromayer has obtained good results in the treatment of over sixty cases of acne vulgaris, rosacea, sycosis, seborrhœa, seborrhœic eczema, etc. It is used in acetone solution as a varnish, leaving a coating on the skin when dry. *W. A. Bastedo.*

EUROBIN, or chrysarobin triacetate, is a dark powder, insoluble in water, but soluble in chloroform, acetone, ether, or acetic acid. Kromayer finds that it causes more reaction than chrysarobin on chronically inflamed skin, as in chronic eczema. He uses it in one to twenty per cent. acetone solution as a varnish. Eugallol or saligallol may be added with advantage.

W. A. Bastedo.

EUROPHEN.—This is one of the many compounds containing iodine and devoid of any disagreeable odor, that have been introduced as substitutes for iodoform. Chemically it is di-isobutylortho-cresol iodide, its formula being $\left(\begin{matrix}C_4H_9\\CH_3\end{matrix} > C_6H_3O\right)_2HI$. Its relation to cresol and iodine is much the same as that of aristol to thymol and iodine.

It is an extremely light amorphous yellow powder, being about five times as bulky as iodoform, with an aromatic odor resembling saffron. It contains 27.6 per cent. of iodine. It is insoluble in water and glycerin, soluble in alcohol up to thirty per cent., and in ether, chloroform, collodion, and fatty oils up to twenty-five per cent. It must be excluded from light and heat, as it is readily decomposed. In contact with water it is slowly decomposed, yielding free iodine.

The use of europhen is indicated in all cases in which iodoform is employed in wounds and ulcers and ulcerated surfaces, and in diseased conditions of the nasal and pharyngeal cavities of the vagina and uterus and all mucous surfaces. In various forms of skin disease it has proved beneficial, especially the acute and chronic eczemas. It is also administered internally in all stages of syphilitic disease, but is recommended as being most active in the third stage, and is thought to replace the iodide of potassium as a specific. The dose to commence with should be one-quarter of a grain, gradually to be increased to one or two grains. If it is administered too rapidly there is a danger of iodism manifesting itself. The same amount may be used hypodermically, a ten-per-cent. solution in oil being prepared for this purpose. For external use as an ointment the following has been selected as an excellent combination: Europhen, 3 parts; olive oil, 7 parts; vaseline, 60 parts; lanolin, 30 parts.

Beaumont Small.

EUSTRONGYLUS GIGAS. See *Nematodes.*

EVOLUTION.—(L. *evolutio*, an unrolling, from *evolvere*, to unroll or unfold.) The term *evolution* has been employed with various meanings:

1. It was used at first in its true etymological meaning of unrolling or unfolding to describe a supposed method of the individual development of organisms.

2. Later it was applied in a metaphorical sense to the origin of species, where it means simply continuous descent with modification, or the origin of species by the alteration of pre-existing species.

3. Finally, we have the metaphysical sense of the word when used as the designation of a system of philosophy that attempts to explain the origin of all things by continuous change. The great exponent of the evolutionary philosophy is Herbert Spencer. The central points in his philosophy are the laws of the indestructibility of matter and the conservation of energy. According to Spencer, the result of these laws is rhythmic motion, manifested everywhere from the dance of molecules to gyrations of planets, and this produces an alternation of evolution and dissolution throughout the universe. Spencer defines this evolution as "change from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity, through continuous differentiations and integrations."

Metaphysics being beyond the scope of the present work, we will confine our attention to the two biological meanings of *evolution.*

Evolution in Ontogeny.—Modern embryology may be said to have begun with the work on the development of the chick which Harvey described in his "Treatise on Generation" in 1651. By means of a hand lens he was able to trace the development of the chick in a general way back to the beginning of the second day. He found that the embryo arises from the light-colored spot in the yolk, called by Fabricius the *cicatricula.* Harvey saw this dilate and become divided into circles, forming what we now call the *area embryonalis,* and this he compared to the iris of the eye and called the *oculum ovi.* At the end of the third day he discovered a fine line of red around the edge of the spot, "and nearly in its centre there appears," he says, "a leaping point of the color of blood so small that when it contracts it almost entirely escapes the eye, when it dilates it shows like the smallest spark of fire. Such is the outset of animal life which the plastic force of nature puts in motion from the most insignificant beginnings." He was unable to distinguish any other parts of the embryo until the fifth day, and he describes in a very interesting way the gradual appearance of the various organs of the embryo as he saw them from that time until the perfect chick is formed.

One of the great generalizations that Harvey made as a result of his observations is known as the theory of *epigenesis.* This is, briefly, that the embryo is built up gradually from a simple beginning by the addition of part to part in a definite order. Harvey regarded the blood as "the first engendered part . . . the source and origin of all other parts . . . which thence obtain their vital heat and become subservient to it in its duties."

It was in opposition to this theory of epigenesis that the theory of *evolution* arose.

Malpighi, working a little later than Harvey, and probably having a better microscope, found that the blood is not the "first engendered part," for he could see an outline of the embryo before the appearance of the "*punctum sanguineum.*" This small detail of observation led Malpighi to reject Harvey's whole theory of epigenesis. He asserted, instead, that the embryo as a whole is present in the egg before incubation, that it is *predelineated.* This led to a great discussion which lasted for more than a hundred years. Of course, if the whole embryo is predelineated in the egg, epigenesis is an impossibility; and development must be a process of *evolution,* an unfolding of the pre-existing embryo. The chief exponent of this theory was Bonnet, who carried it out to its logical conclusion (1762), and asserted that development is not only a process of evolution, but also that all germs have existed since the day of creation, and that each embryo contains in similar form the germs of all subsequent generations.

The theory of evolution seems, on the whole, to have prevailed as the generally accepted explanation of development until 1812, when Meckel called attention to a Latin treatise, "Theoria Generationis," published in 1759 by Caspar Frederick Wolff, as the dissertation for his doctor's degree. In this paper Wolff had traced the development of both the chick and certain flowering plants back to very simple beginnings, and he showed that the development is really an epigenesis and not an evolution. This view has been fully confirmed by the vast amount of research in embryology that has been carried out during the latter half of the nineteenth century.

The almost mediæval theory of evolution of Bonnet and his friends seems so absurd to-day that it would hardly be worth mentioning if it were not for the fact that the theory has been revived recently in a more subtle form.

To be sure the individual development of organisms, so far as we can see with the eye or with the most powerful microscopes, is clearly a process of epigenesis. But, after all, there is much that still remains invisible, and the utmost limits of our vision include only superficial manifestations of forces working within the protoplasm. May it not, then, be true that the embryo is really preformed in invisible particles within the germ-plasm? May not differentiation be in essence merely the visualization of pre-existing invisible potentialities? If we answer these questions in the affirmative, our explanation of ontogeny is as much evolution as was Bonnet's. There has been much discussion of this subject within the past ten years, but it is so intimately connected with the theories of heredity that it will be more conveniently reviewed in connection with that subject (see *Heredity*).

Organic Evolution.—Usually when one speaks of evolution one means what has been called *organic evolution*, the origin of diversity in the organic world by means of natural processes.

The opposing theory is that of *special creation*. According to this latter view, each species was established in the beginning by a miraculous act of creation. Each species is, then, a distinct and concrete phenomenon of nature. There is but one true classification which is to be discovered, not invented, by naturalists.

From the point of view of evolution, on the other hand, the great fact of nature is the diversity of organic forms, and no sharp line can be drawn between varieties, species, genera, and families. A classification is merely a convenient invention of the human mind to summarize the present state of knowledge in regard to the structure of organisms, and must change from time to time as such knowledge increases. The idea of miraculous intervention is rejected, and the effort is to discover in the organic world the same orderly working of the laws of nature that has been found to obtain in the inorganic world.

In regard to evolution, it must be borne in mind that two questions are involved: First, does the theory of evolution, as a whole, furnish a better summary of our knowledge of organisms than the theory of special creation? In other words, is evolution to be regarded as an historical fact? Second, what are the factors into which the theory of evolution may be resolved, or, how may the fact of evolution be explained as a process?

While there is much difference of opinion among naturalists in regard to the second question, the first is to-day answered by almost every man of science in the affirmative. On the other hand, there are many persons who have not paid especial attention to natural history and who still hold to the doctrine of special creation. Therefore, it may be well to give a brief summary of the evidence on which men of science base their belief in evolution as a fact.

The Evidence of Evolution.—1. In the first place, we have the *analogy of the other sciences*. For the ancients the sun, the moon, and the planets were controlled in their movements by attendant spirits. Until well into the nineteenth century the structure of the earth was explained as the result of a series of catastrophes accompanied by changes in the order of nature. But Newton showed that the movements of the planets could be described by the same formula that describes the falling of a stone, and the result of the labors of Hutton, Lyell, and their successors, has been to show that the structure of the earth may be explained as the gradual effect of forces now to be observed at work upon the earth's surface. In a similar way, in physics and chemistry the supernatural has been replaced by the natural, until the doctrine of special creation, if accepted, would remain the only exception to the general rule that all phenomena of nature are to be explained by natural laws.

When we say "explained" it must be borne in mind that, in reality, science explains nothing. What science really does is to describe phenomena by means of brief formulæ that summarize the greatest possible amount of knowledge. A "natural law" is not an object of nature, it can do nothing. It is merely a human invention to summarize man's experience of the past and his belief as to the future. When we say that a stone falls with the velocity, $v = gt$, we mean that, whenever the experiment has been tried under proper conditions, this formula has been found to describe truly the result, and we have no reason to believe that it will not always be found to be true in the future. And this is all we mean when we say that the stone falls because of the law of gravitation. In ordinary language we are said to have explained the fall of the stone, but, in fact, we do not know what gravitation is, and we know no more *why* the stone falls than we did before. The common error of deifying natural law may be avoided if we remember that a natural law is a description of a sequence of events that may be expected to occur always in the same order under the same conditions, and an event is explained, or "made plain," when referred to its proper place in this sequence.

Now the question before the naturalist is, Shall the factor of special creation be included in the formula descriptive of the diversity of form in the organic world? We have seen that in all the other sciences the supernatural factors have been rejected as superfluous, therefore from analogy it is *a priori* probable this factor should be rejected also in biological theory, including the theory of the origin of species.

2. Turning now to the results of observation, it is evident that from the doctrine of special creation it would be impossible to predict anything in regard to the *classification* of animals and plants, except that it might be supposed that species would be fairly distinct. From the theory of evolution, on the contrary, it might be expected that it would be difficult in many cases to distinguish between varieties and species on the one hand, and between species and genera on the other. Moreover, it would be expected that, to show their true affinities, in the classification the species would have to be arranged like the buds on a tree, in which the buds are the species, while the twigs, the branches, and the stem would represent their hypothetical lines of descent. These two predictions are fully verified in practice, and the theory is to that extent confirmed.

3. The classification of species leads directly to the study of their *geographical distribution*. The theory of evolution assumes that each species began with relatively few individuals in a restricted locality, from which it spread as the number of individuals increased until it reached its maximum extension. Thus far the theory of special creation might agree. But it would deny the further assumption, that each genus was at first a single species which, as it gradually extended its area of distribution, became exposed to different conditions in different parts of this area, and that, as a result of the operation of natural laws, the individuals in these different sections became changed in the course of generations so as to constitute distinct varieties and later species.

As a corollary to this theorem of evolution, we should expect that the more inclusive a group, the wider would be its range. The length of time required for the evolution of an order would probably be greater than for that of a genus, hence there would be more time for migration and, consequently, a wider range.

Another corrollary is that there should be a close relation between the affinities of the organisms in any area and the physical barriers separating it from other areas.

The study of geographical distribution confirms these predictions. It is found that, while some species have a cosmopolitan range, most species have more restricted ranges than the genera to which they belong, and the genera in turn have smaller ranges than their families and orders.

The affinities of species in any region are found, in fact, to depend more upon the position of barriers than upon the climate or other conditions. This is shown by a comparison of the productions of the Northern hemisphere with those of the more isolated areas of the Southern hemisphere. Oceanic islands, as compared to continental islands, furnish also important evidence on this point.

It must not be forgotten, however, that the facts of geographical distribution present some difficulties for the theory of evolution. But, while some of these still remain to be solved, most of them have been cleared up by a study of the past history of the earth and the geological sequence and distribution of organisms.

4. It might be expected that a study of *palæontology* would furnish the very best evidence of evolution, if it were not for the fact that the preservation of organisms as fossils depends on so many factors of chance that the odds against the preservation of any individual, or even any species, are very high, and the odds against its being both preserved and discovered by palæontologists are still higher. Nevertheless, palæontology has furnished much evidence, and, so far as it goes, it all supports the theory.

In the first place, the evidence from palæontology supplements that from the present geographical distribution by showing the geographical distribution in previous geological periods, and thus making it possible to trace the migrations of forms and to explain their present distribution. In some areas there is a marked similarity between species now living on the surface and the fossils found in the underlying deposits. In cases in which the present distribution is discontinuous to a marked degree, as in the marsupials, tapirs, and camels, it has been found that during earlier periods they occupied intermediate areas.

Direct evidence is furnished by the study of the succession of forms in geological time. In general it may be said that, the farther back we go in time, the less differentiated the forms appear. And in a few series, such as the camels and the horses, it has been possible to trace very completely the line of descent from a very generalized type to the highly differentiated forms now living. The study of such a series leaves one with very little doubt as to the fact of evolution.

5. But the fossils are not the only source of information in regard to the past history of species. Each individual may give in the course of its development an abbreviated and simplified picture of the history of its race. At least, such is the inference drawn from a large body of fact furnished by the study of *embryology*. It has been found, as a general rule, that the earlier stages in the development of any form correspond to the more generalized, lower, types of the same group. And in some cases, for example, the fishes, it has been shown that the succession of these stages of gradually increasing differentiation correspond with the succession of forms in geological time. This is exactly what would be expected on the theory of evolution. On the theory of special creation one would expect the development of the individual to take place in as direct a manner as possible, unless there is some physical necessity for the indirect methods which give the appearance of recapitulation of ancestral history. That there is no such necessity is shown by the absence of these ancestral stages in the development of many species, while they are present in related forms, and by the fact that two individuals may reach a practically identical adult structure by entirely different modes of development, as, for example, individuals developed from buds and from eggs of the same species (see article *Budding*).

6. Further evidence of the past history of a species is furnished by the presence of *vestigial organs*, organs that are arrested in development and are apparently of no use to the species in which they occur, but which are homologous with fully developed functional organs in other, usually lower, species of the same or related groups. The human body contains a great number of such vestiges. They are perfectly unintelligible on the theory of special creation, and perfectly in harmony with the theory of evolution.

7. The study of comparative anatomy affords also another line of evidence concerning evolution. This is found in the distribution of *homologous organs*. If each species has been created separately there is no reason why organs constructed on the same fundamental plan, that is homologous organs, should not be found in any number of species. But if, on the contrary, the numerous species in any great group have arisen by the diversification of a relatively simple undifferentiated type, then we would expect the species in one group to show their common origin in similarity of plan of structure, and we would expect them to differ in plan of structure from species of another group having a different origin, although their organs might be called upon to perform similar functions.

Now this is just what we do find to be the case. An internal digestive tract is a fundamental characteristic of all animals above the Protozoa, and we can regard it as probably more or less homologous in all species. But when we come to less fundamental structures, such as legs, wings, and eyes, it is found that the homologies between species are confined to their own great groups. For example, although the wing of an insect and the wing of a bird have exactly analogous functions, they are not in any degree homologous. On the other hand, the wing of a bird and the wing of a bat, while differing in detail, have the same architectural plan, which is also the same as that of the arm of man and the foreleg of a horse. Thus the fore-limb throughout the vertebrate series is homologous, although differing greatly in function. This is but one of a great many similar facts, all of which go to show that the vertebrates are derived from a common ancestral type. In the same way the eyes are homologous in all vertebrates, and are not homologous with those of any other group. Mivart thought he had found an homology in the eye of the squid. In its optical principles and general form this eye resembles that of a vertebrate very closely. But a careful examination of its mode of development and minute structure shows that it is formed upon an entirely different plan.

Looking back over these seven lines of evidence, we find that, while they present some difficulties, these are all capable of explanation from the point of view of evolution; and these lines of evidence support and supplement one another so completely that the man of science appears to be justified in accepting evolution as a fact, provided he can construct a valid theory to explain or describe the method of evolution.

History of the Theories of Evolution.—The idea of evolution appears in the speculations of the "nature philosophers" of the last decade of the eighteenth century and the first decade of the nineteenth. According to Osborn, this is largely due to the influence of the Greek philosophers. At any rate, the idea seems to have been in the air at this time, for several of these men suggested more or less independently of one another that species are not fixed things, but are subject to change, and that their present form is the result of such change. In each case, however, it was more the groping after a theory than the formation of one, and what was of scientific value was often hidden by the fanciful and absurd. The question was chiefly as to evolution as a fact, and little attempt was made to answer the question as to method, as to how evolution could be brought about.

The first consistent attempt to answer this question of method was made by Lamarck in the year 1809 in his "Philosophie Zoologique." According to Lamarck, "the systematic divisions of classes, orders, families, genera, and species, as well as their designations, are the arbitrary and artificial productions of man. The kinds or species of organisms are of unequal age, developed one after the other, and show only a relative and temporary persistence; species arise out of varieties. The difference in the conditions of life have a modifying influence on the organization, the general form, and the parts of animals, and so have the use and disuse of organs. In the first beginning only the very simplest and lowest animals and plants come into existence; those of a more complex organization only at a later period. The course of the earth's development and that of its organic inhabitants was continuous, not interrupted by violent revolutions." He not only asserted as others had done that species have developed, but he gave an answer to the question, How? It is a well-known fact that muscles and other parts that are much used grow stronger, become harder, or are modified in some way that is usually of advantage, while parts that are not used tend to dwindle. Lamarck believed that species are subject to a continued transformation by the inheritance of the results of use and disuse. As the use and disuse of organs is determined by the habits of the individual, Lamarck regarded habit as the chief cause of evolution. An animal's wish to do a certain sort of thing and his constant striving to do it resulted in a change of structure in his descendants that would render them better able to do this thing. On the face of it, it seems reasonable enough to suppose that the well-known effects of use and disuse are inherited, and that varieties and finally whole species have arisen or have suffered change in that manner. But, when Lamarck attempted to carry out this theory in detail, he ran into manifest absurdities, as, for instance, when he attributes the long neck of the giraffe to its habit of striving to reach the leaves of trees. It was perhaps as much on account of the number of such absurdities, as on account of the advance beyond its age, that this work of Lamarck's remained for a long time in obscurity, and was not even mentioned by such men as Goethe and Cuvier, although Lamarck held a high rank by reason of his other works, especially his "Histoire Naturelle des Animaux sans Vertèbres," published in 1815–22.

Another Frenchman, Etienne Geoffroy St. Hilaire, arrived at a similar theory of evolution at about the same time that Lamarck did, but he did not publish until 1828 and 1830. His theory was the same as Lamarck's, except that he laid less stress on habit and the inherited effects of use and disuse and more on changes in external conditions. His most important contribution is the idea of permanence of sports giving rise to new varieties and species. He attacked Cuvier's theory that the animal kingdom presents four great independent types of structure—radiate, articulate, molluscan, and vertebrate—and attempted to prove that the whole animal kingdom is formed upon a single structural plan. This gave rise to a dispute which culminated in the famous debates of February 22d and July 19th, 1830, in which Cuvier, with his superior knowledge of comparative anatomy, came off the victor.

From this time on for nearly thirty years the believers in special creation and the permanence of species rested assured of their position, relying on the wide knowledge and high authority of Cuvier. They little dreamed of the volcano beneath their feet. For the echoes of the famous debate of 1830 had hardly died away when Charles Darwin started on a voyage that was to have for its chief result the greatest revolution in thought of modern times.

When Darwin started on his voyage in the *Beagle* in 1831, he took with him a copy of Lyell's "Principles of Geology," and he was thus predisposed to regard the phenomena of nature as occurring in an orderly and uninterrupted sequence; moreover, there was in this book a discussion of Lamarck's theory, so that this must also have been fresh in his mind. From his autobiography (p. 82) we learn that he had been "deeply impressed by discovering in the Pampean formation great fossil animals covered with armor like that on existing armadillos; secondly, by the manner in which closely allied animals replace one another in proceeding southward on the continent; and thirdly, by the South American character of most of the productions of the Galapagos Archipelago, and more especially by the manner in which they differ slightly on each island of the group; none of the islands appearing to be very ancient in a geological sense." It seemed to him that such facts, as well as many others could be explained only by the supposition that species gradually become modified. But it seemed to him equally evident that neither the action of the surrounding condition, as Geoffroy St. Hilaire thought, nor the will of the organisms, as Lamarck supposed, could account for the innumerable cases in which organisms of every kind are beautifully adapted to their habits of life. In 1837 Darwin began to collect evidence, in the hope of obtaining some light on the subject. So far he had gone no farther than his predecessors. He had found much evidence for a theory of descent, but the question, How? still remained unanswered. In collecting facts he paid special attention to the modifications of domestic species, and soon came to the conclusion that in these cases "selection was the keystone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery."

In October, 1838, Darwin happened to read for amusement Thomas Robert Malthus's "Essay on the Principle of Population" (1803), and then the solution of the problem flashed upon him. Malthus quotes from Benjamin Franklin's "Observations Concerning the Increase of Mankind" (1751) the remark that "there is no bound to the prolific nature of plants or animals but what is made by their crowding and interfering with each other's means of subsistence." He applies this, as Franklin did, to mankind, and he shows, moreover, that man tends to increase in a geometrical progression, and that if it were not for checks on population, the number of human beings on the earth would be doubled at least once in every twenty-five years. And, further, while population tends to increase in geometrical ratio the food supply, according to Malthus, can be increased only at most in an arithmetical ratio. As population tends to increase faster than the food supply, the lack of food soon becomes the principal check to further increase. Darwin, from his long-continued observation of the habits of animals and plants, was well prepared to appreciate the struggle for existence which goes on everywhere as the result of this law of increase, and it struck him at once "that under these circumstances favorable variations would tend to be preserved and unfavorable ones to be destroyed. The result of this would be the formation of new species." Darwin called this the process of *natural selection.* With characteristic caution, he did not even permit himself to write out his theory for a long time, but continued searching for evidence for and against it.

In the mean time, Alfred Russell Wallace made a journey to the Malay Archipelago. Like Darwin, he was much impressed by the evidences that he found for the evolution of species. While in Borneo in February, 1855, he wrote a paper on this subject that was published in the *Annals and Magazine of Natural History* in the following September. In this paper he stated the law that, "Every species has come into existence coincident, both in space and time, with a pre-existing, closely allied species." This is the next thing to saying that every species has been evolved from a pre-existing, closely allied species. Wallace evidently hesitated to state the law in this form because he had no theory to offer as to the manner in which evolution is brought about. He brought forward the evidence from classification, from geographical distribution, palæontology, and vestigial organs; and the law that has been quoted was the final result of this paper. The question, "How?" still haunted him, however. Three years later, Mr. Wallace was at Ternate in the Moluccas and, while confined to his bed by fever, he was meditating on this problem. The "positive checks" occurred to him—war, disease, famine, and the like—described by Malthus in his "Essay on Population." He saw that these must apply to the animals as well as to man, and he thought of the much more rapid multiplication of animals, and then there suddenly flashed upon him the idea of the survival of the fittest, "that the individuals removed by these checks must be on the whole inferior to those that survive." Three days later a paper embodying this theory was written and on its way to England, addressed, strange to say, to Mr. Darwin, who had been working on this same theory for years. The immediate result was that Darwin was reluctantly persuaded to publish an abstract of his work, together with Wallace's paper, and the two appeared in the *Journal of the Proceedings of the Linnean Society* for 1858 ("Zool.," vol. iii., 1858, p. 45). In 1859 the "Origin of Species" was given to the world and gave the impetus to that great revolution in thought to which we have already referred.

We certainly cannot honor too highly the pure love of truth and devotion to science, uncontaminated by ambition for fame, which we see in these two men, and we are especially called upon to admire the loyal and ungrudging way in which Wallace attributes all the honor of the great discovery to Darwin. It is of interest to us Americans to note that the man who furnished the necessary cue to both Darwin and Wallace, Thomas Robert Malthus, received it in turn from our fellow-countryman, Benjamin Franklin.

We are indebted to Darwin for the first presentation of a theory of evolution that carried with it conviction to the scientific mind. Because it did carry conviction it was attacked with great vigor on all sides, scientific and unscientific alike. The younger generation of to-day can hardly appreciate the bitterness of the struggle between the advocates of tradition and those of the new idea.

As men of science gradually became convinced of the fact of evolution, there arose a calmer discussion as to the method. Some have held that natural selection is the sole factor; others, that it is the prime factor, but that it is supplemented by other factors; then there are the "neo-Lamarckians," who hold that, while natural selection is a factor, it is one of minor importance compared to the inheritance of acquired modifications. We will turn now to a very brief consideration of each of these factors.

Factors of Organic Evolution, Variation.—Variation may be defined as deviation from the type of the species, race, or family, or from whatever may be taken as the standard. Without variation there could be no change of type, and variation must, therefore, be at the basis of every theory of evolution.

So long as species were regarded as fixed, immutable objects of nature variations were generally disregarded. Thus, when Darwin began to collect data on the subject he found few recorded observations. While he succeeded in finding much evidence of variability in domestic races, he supposed variations of wild races to be relatively infrequent and slight in amount. Wallace was the first to point out that wild species are frequently highly variable. During the past decade a great deal of attention has been paid to variation, and a considerable amount of literature has accumulated on the subject.

It has been found that all characteristics of organisms are subject to variation. Some variations are *congenital*, that is, apparently independent of the environment; while others are *acquired modifications* due to a reaction of the organism to a definite factor in the environment.

Variations may be *abnormal*, that is, wide and infrequent departures from the type, such as the horticulturists call *sports;* or they may be *normal*, occurring in varying degrees in a majority of the individuals of the species, as, for example, variations of stature in man.

The first quantitative measurements of variation were made by J. A. Allen in 1871. Galton a little later introduced the statistical treatment of variations, and Pearson has shown how they may be subjected to accurate mathematical analysis. The subject will be treated here only so far as may be necessary for the understanding of natural selection. (For more extended treatment, see article *Variation.*)

Most persons regard "chance" as something entirely apart from law—something which cannot be predicted. But the mathematicians have shown long ago that chance is subject to strict mathematical laws. Single events cannot be predicted, it is true, but the general result can be predicted with certainty. For example, Weldon has published the results of four series of experiments in throwing dice. In each series there were 4,096 throws of 12 dice, and at each throw the number of dice having more than three points on the upper side were counted and recorded. The frequency with which 1, 2, 3, etc., dice showed more than three points was tabulated—and the results, when plotted, were found to follow very closely the theoretical curve of chance, which is described by an exact mathematical formula. Now it is found in a large number of cases that the variations in the characters of organisms which can be determined accurately—by counting, as the number of ray flowers in the daisy; or by measurement, as the length of a man's head—when tabulated and plotted occur with the frequencies predicted by the law of chance. So we may say that normal variations occur, as a rule, by chance.

This is best illustrated by an example. In the course of investigations carried on under the direction of the writer, measurements were made of the width of the angle at the apex of the shell in ninety-seven specimens of *Purpura lapillus*, a marine snail common on the New England coast. The results were tabulated as follows:

	Classes.				
Width of angle in degrees ..	60–65	65–70	70–75	75–80	80–85
Frequency	3	21	45	24	4

These results may be represented graphically by the five rectangles in Fig. 1945, where the limits of the class are represented by the width of the rectangle, and the height represents the number of individuals included, or its frequency. It will be noticed that the middle rectangle is the highest and, therefore, represents the most frequent class. This has been called the *mode*, or model class, and may be taken as representing the *type* of apical angle for the species. It will be noticed also that the classes having the least frequency are those farthest removed from the mode. By some easy mathematics one may readily obtain the general average, or arithmetical *mean*, of all the measurements, which in this case is

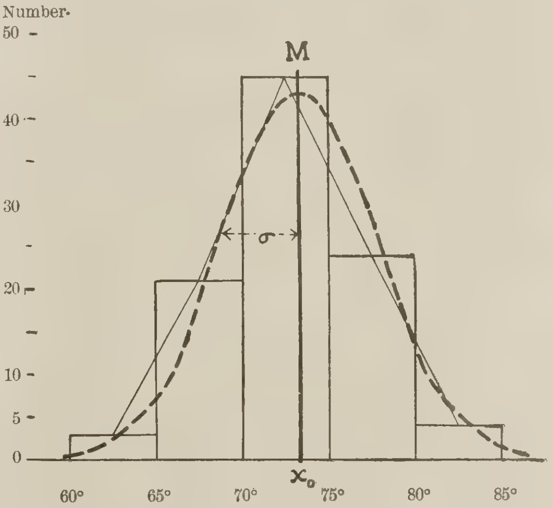

FIG. 1945.—Graphic Representation of a Series of Variations. Variation in the width of the angle at the apex of the shell in *Purpura lapillus*.

73.26°, and on the diagram (Fig. 1945) is represented by the position of the line Mx_0. The mean of any character may be taken also as the *type* for the species, and this is used much more frequently than the mode as the standard from which to measure variations. We may obtain a rough idea of the variability of a character by observing the extreme *range* of variation from the lowest to the highest value. But this cannot be done very accurately and conveys no information as to the relative frequency of the intermediate values. A better idea may be obtained by calculating what is called the *standard deviation* ($\sigma = \sqrt{\frac{\Sigma(x^2f)}{n}}$, see article *Variation*). In our example this has the value of 4.36°, and is represented at σ in the diagram. Knowing the total number of individuals measured, the mean, and the standard deviation, it is possible by the use of appropriate formulæ and tables (Davenport, "Statistical Methods") to calculate and plot the corresponding theoretical *normal curve* of chance. This is represented in the diagram by the heavy broken line. This means that if, instead of taking ninety-seven individuals and dividing them into five classes, we had taken a very large number of individuals, several thousand at least, and divided them into very many classes, we should expect to obtain a series of rectangles, the tops of which would follow the broken line; and in our diagram it will be noticed that the straight lines connecting the middle points in the tops of the rectangles follow pretty closely the theoretical curve. Thus, although only ninety-seven specimens were taken, much too few for accurate results, it is evident that the different variations in the acuteness of the apex in Purpura occur approximately with the frequency predicted by the law of chance. In calculating this curve it has been assumed that the mode and the mean coincide and that variations less than the mean and those greater than the mean occur normally with equal frequency, so that the curve is perfectly symmetrical. In many cases, however, it has been found that the frequency of variations is best represented by a curve where the mean and the mode do not coincide. In such cases the curve is asymmetrical, and is called a *skew curve.*

In other cases it has been found that there are two or more classes containing a large number of individuals with intermediate classes containing few. The curve plotted from such a series of observations would present two or more modes, as the case might be, and would be what is called a *multimodal curve.* An example of such a curve is shown in Fig. 1946, which represents the distribution of variations in the width of the leaf of the cat-tail. The data from which the curve is plotted are obtained from measurements of the widest part of the widest leaf in two hundred and fifty specimens, and are as follows:

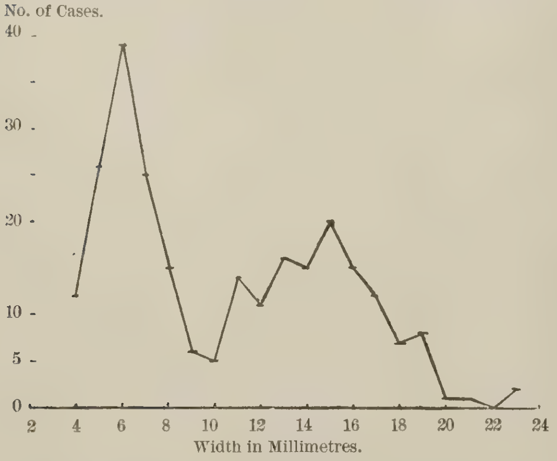

FIG. 1946.—Example of a Multimodal Curve. Variation in the width of the leaf of the cat-tail, *Typha latifolia* and *T. angustifolia.* (After Blankinship.)

CLASSES.

Width in milli-metres.	Number of cases.	Width in milli-metres.	Number of cases.	Width in milli-metres.	Number of cases.
4	12	11	14	18	7
5	26	12	11	19	8
6	**39**	13	16	20	1
7	25	14	15	21	1
8	15	**15**	**20**	22	0
9	6	16	15	23	2
10	5	17	12		

After allowing for minor irregularities, due probably to the small number of observations, there are evidently two modes, one at 6 mm. and the other at 15.

This illustrates the distinction between *individual variation* and *racial variation.* So long as the variations are distributed about a single type we have what is called individual variation, and the variability of the species in respect to the character in question is measured by its standard deviation. But where there are several modes—several types about which variations are distributed—we have what may be called racial variation, and this kind of variability is measured by the number of modes and their distance apart. Racial variability tends to divide the species into races, or sub-species. In fact, botanists divide the cat-tails into two distinct species, *Typha latifolia* L. and *T. angustifolia* L. But Blankinship has shown that these two groups grade into one another in all their characters, and this is a good example of the difficulty, often met with, of drawing a sharp line between species.

So far single variations have been treated as if they were isolated objects. As a matter of fact, they never occur as such in nature, for every individual is made up of a great many characters; and the question arises, Is there any relation between the deviation of one character and the deviations of other characters in the same individual? Such a relation is called the *correlation of variations,* and Darwin gave many interesting examples of it. Since then Galton has pointed out a method by which correlation may be studied very exactly, and the degree of correlation may be given mathematical expression. If in a number of individuals character A deviates from its mean Ma by the amount Xa, it is possible to determine what will be the average deviation Xb of the character B from its mean Mb (see article *Variation*).

While much work is still to be done in this line, enough has been accomplished to show that correlations of this kind are common among normal variations; and this is a fact of the highest importance for the theory of evolution.

Heredity.—Heredity is a special case of correlation. It is the correlation between the variations of homologous organs in individuals related by birth, especially those in the relation of parent and offspring. The facts of heredity are of equal importance with the facts of variation. For if this correlation did not exist, or, to use the common metaphor, if there were no inheritance of variations, progressive change of type, evolution, would be as impossible as if there were no variation at all.

The facts and theories of inheritance will be discussed more fully elsewhere (see articles *Heredity* and *Reversion*). Attention here will be confined to a few facts of especial importance in connection with the subject of the present article.

In the first place it may be noted that there are three chief forms of inheritance: (1) *Blended* inheritance where the character in the offspring partakes of the qualities of both parents, as in stature; (2) *exclusive* inheritance, where the character in the child is like that in one parent, but not like the other, if it differ from the first, as in the color of the eye; (3) *particulate* inheritance, where the child resembles one parent in one character and the other in another character. For example, a child may have its mother's eyes and its father's nose.

In general, all congenital characters, whether they be new acquisitions or inheritances, may be transmitted to the offspring. But it is extremely doubtful if acquired modifications are ever inherited (see p. 35). Sometimes the correlation of the offspring will be much stronger with one parent than with the other, and the parent which the offspring tends to resemble the most is then said to be *preportent.* This is often the case with sports, as in the famous Ancon breed of sheep that arose in Massachusetts in the latter part of the eighteenth century. In domestic races pure bred animals are generally prepotent over mongrels.

Heredity is *measured* in the same way that correlation is. But a complication arises owing to the fact that most individuals have two parents. In order to avoid the difficulty of measuring the correlation of three variables, the two parents are combined into one imaginary individual known as the *mid-parent.* Then it is easy to find the correlation between mid-parent and offspring.

Pearson gives the following formula for finding the mid-parent:

$$\frac{1}{2}\left(h_1 + \frac{\sigma_1}{\sigma_2}\, h_2\right) = H$$

where h_1 = value of the character in the father, h_2 = the same in mother, σ_1 = standard deviation of fathers in general, σ_2 = the same for mothers, and H = the character in the mid-parent.

It might be expected that the average offspring would be like the mid-parent. But, as a matter of fact, it is found by observation that, while some children may be exactly like the mid-parent and some more peculiar, the average of the offspring will be less peculiar, more nearly like the general average of the population, than the mid-parent, if that be possible. This is called *regression.* The amount of regression differs with different characters in different species, but in general it may be said that the offspring on the average will be about two-thirds as peculiar as the mid-parent, or one-third as either parent considered alone. This may be accounted for, perhaps, by reference to the previous ancestry. For if there be no selection or inbreeding, the number of ancestors in each generation increase as we go backward in geometrical ratio until they soon form all together a fair sample of the population as a whole. In the tenth generation back there are ten hundred and twenty-four ancestors.

On the other hand, we have the seemingly paradoxical fact of regression in the opposite sense. That is, if we take a large number of children all deviating in a certain character to a given degree from the average of the population, it will be found that the average of their mid-parents will be only one-third as peculiar. This is simply due to the fact that mediocre mid-parents are more common than peculiar ones (see Fig. 1945). From these facts Galton has derived a law of heredity, which Pearson states in the following words:

"Each parent contributes on an average one-quarter, or $(\frac{1}{2})^2$, each grandparent one-sixteenth, or $(\frac{1}{2})^4$, and so on, and that generally the occupier of each ancestral place in the *n*th degree, whatever the value of *n*, contributes $(\frac{1}{2})^{2n}$ of the heritage."

Mathematically this would be,

$$h = \tfrac{1}{2}\,\mathrm{H}_1 + \tfrac{1}{4}\,\mathrm{H}_2 + \tfrac{1}{8}\,\mathrm{H}_3 + \ldots \text{etc.},$$

a geometrical progression approaching a limit = 1, when h = the average deviation of the offspring, and H_1, H_2, H_3, etc., = the deviation in the mid-parent, mid-grandparent, mid-great-grandparent, etc. But Galton's series, $\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \ldots \frac{1}{1024}$, etc., may not be true in all cases. So Pearson replaces these figures by symbols that may express any geometrical progression, γa, γa^2, γa^3, . . . γa^{10}, etc., in which there are two factors, one constant in each generation, γ, and one which varies in geometrical series, a, a^2, a^3, etc.* Then allowing for difference of variability, as well as differences in deviation and mean, of past generations of mid-parents, Pearson gets the following *law of ancestral* heredity:

$$h = \gamma \left\{ \frac{1}{1+\gamma,}\,\frac{\sigma}{\sigma_1}\,\mathrm{H}_1 + \frac{1}{(1+\gamma)^2}\,\frac{\sigma}{\sigma_2}\,\mathrm{H}_2 +, \ldots \right.$$
$$\left. \frac{1}{(1+\gamma)^{10}}\,\frac{\sigma}{\sigma_{10}}\,\mathrm{H}_{10} + \ldots, \text{etc.} \right\}$$

where h = average deviation of the offspring, H_1, H_2, H_3, etc. = the deviation from the means of their generation of the mid-parents, mid-grandparents, etc., σ = standard deviation, variability, of all offspring, σ_1, σ_2, σ_3, etc. = variability of the race in the generations to which the successive mid-parents belong, and γ is the *constant of heredity,* upon which all hereditary influence depends. This, in Mr. Galton's formula, would be $\gamma = 1$. But it may be found to vary in different species and in different organs.

As to the importance of the law of ancestral heredity, Pearson says: "If Darwinism be the true view of evolution, *i.e.,* if we are to describe evolution by natural selection combined with heredity, then the law which gives us definitely and concisely the type of the offspring in terms of ancestral peculiarities is at once the foundation stone of biology and the basis upon which heredity becomes an exact branch of science."

The Struggle for Existence.—With the struggle for existence we come to the first of the distinctively Darwinian factors of evolution.

Darwin's definition is as follows. He says: "I should premise that I use this term in a large and metaphorical sense, including dependence of one being on another, and including not only the life of the individual, but success in leaving progeny. Two canine animals, in a time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought, though more properly it should be said to be dependent on the moisture. A plant which annually produces a thousand seeds, of which only one of an average comes to maturity, may be more truly said to struggle with the plants of the same and other kinds which already clothe the ground. The mistletoe is dependent on the apple and a few other trees, but can only in a far-fetched sense be said to struggle with these trees, for, if too many of these parasites grow on the same tree, it languishes and dies. But several seedling mistletoes growing close together on the same branch may more truly be said to struggle with each other. As the mistletoe is disseminated by birds, its existence depends on them; and it may metaphorically be said to struggle with other fruit-bearing plants, in tempting the birds to devour and thus disseminate its seeds. In these several senses, which pass into each other, I use for convenience's sake the general term struggle for existence" ("Origin of Species," 6th ed. vol. i., p. 78).

Wallace uses the term without giving a definition. In his essay of 1858 he says: "The life of wild animals is a struggle for existence. The full exertion of all their faculties and all their energies is required to preserve their own existence and provide for that of their infant offspring. The possibility of procuring food during the least favorable seasons, and of escaping the attacks of their most dangerous enemies, are the primary conditions which determine the existence both of individuals and of entire species."

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* Then substituting, we have:

$$h = \gamma\,(a\,\mathrm{H}_1 + a^2\,\mathrm{H}_2 + a^3\,\mathrm{H}_3 + \ldots \text{etc.}).$$

Now when $\gamma\,(a + a^2 + a^3 + \ldots \text{etc.}) = 1$, then $\frac{\gamma a}{1-a} = 1$

$\therefore \gamma = \frac{1-a}{a} = \frac{1}{a} - 1. \quad \therefore \frac{1}{a} = 1 + \gamma$, and $a = \frac{1}{1+\gamma}$.

So a, a^2, a^3, . . . a^{10} . . ., etc., may be replaced in the formula by

$\frac{1}{1+\gamma}\ \frac{1}{(1+\gamma)^2} \ldots \frac{1}{(1+\gamma)^{10}} \ldots$, etc.

This term, struggle for existence, is a convenient one, and it conveys a very vivid impression as to what takes place. But it may convey a false idea unless we are careful to bear in mind the metaphorical character of the expression. It may help us to do this if we can find for this term a definition which in itself shall be free from metaphors.

Spencer has defined life as "the continuous adjustment of internal relations to external relations" ("Principles of Biology," 2d ed., vol. i., p. 99). So long as the external relations are favorable, this adjustment is made easily. When they become unfavorable it is made with difficulty, and when it becomes impossible the organism dies. Therefore we may define the struggle for existence as the tendency of organisms to preserve a continuous adjustment of internal relations to unfavorable external relations.

The meaning of this will be more clear when we consider what are these unfavorable external relations in which life becomes a struggle for existence. They may be classified under three divisions: (1) adverse physical conditions, (2) enemies, and (3) competition.

1. *The Struggle against Adverse Physical Conditions.*—Conditions that are adverse for one species may be favorable for another. Thus the polar bear is unable to live on the hot sands of the Sahara, and the polar ice fields would be equally fatal to the lion. A fish cannot live in the air, nor a bird under water. So what constitutes an unfavorable physical condition depends largely upon the constitution of the organism that meets it.

There are doubtless large numbers of individuals and species which, so long as they remain in their native habitat, never have to contend with adverse physical conditions. Such is true, for example, of the majority of dwellers in the sea, and it applies equally well to the inhabitants of many tropical lands. The islands of the Antilles with their abundant rains, and even, warm temperature, are as favorable as possible for life. The only unfavorable condition is the occasional hurricane, when the rivers "come down," as they say, in irresistible torrents and the wind tears huge trees up by the roots, while the seas dash against the shores with appalling fury. Except for these infrequent catastrophes, the processes of life are favored continually by the physical conditions on land as well as in the sea.

It is in our own temperate region, with its extremes of heat and cold and sudden changes from moisture to dryness, that the adjustment of internal relations to external relations is attended with difficulty. We see this adjustment taking place annually at the time of the falling of the leaf, when the trees prepare themselves to withstand the frosts of winter. The leaves are cut off by an ingrowth of bark. The absorption of water is suspended, and the protoplasm becomes concentrated in the cells already heavily laden with starch. The embryonic tissue is confined to a thin layer under the bark and to small areas in the buds protected by thick envelopes, often lined with down, and varnished on the outside; and the cells of other parts acquire a thick wall of cellulose which renders them incapable of further growth. Thus in the cool days of fall the trees prepare to resist the freezing of winter, and usually this is successful. But sometimes it fails.

The summer of 1879 in England was cool and damp so that the new wood was not properly matured. This was followed by an unusually severe winter, and all over the country thousands of perennial plants were killed or severely injured by freezing. In one locality every common shrub was killed to the ground (Henslow, "Frost Report," 1887). In this country it happens frequently that warm days in early spring tempt the trees to throw off their winter protection, and send forth the young shoots and flower-buds. Then comes a late frost, and all the growing parts are killed.

But extreme cold is even more disastrous to animals. Darwin says: "I estimated (chiefly from the greatly reduced numbers of nests in the spring) that the winter of 1854–55 destroyed four-fifths of the birds in my own grounds." After the great storm of February 1st, 1898, Professor Bumpus found one hundred and thirty-six sparrows lying helpless upon the ground in Providence, of which sixty-four were dead or dying.

The effects of drought upon animals as well as plants are so well known that they need not be described.

2. *Enemies.*—Darwin regards extremes of cold and drought as probably the most effective of all checks on population. But the depredations of enemies constitute a check which is even of more universal effect.

Ernest Seton Thompson says: "The life of a wild animal *always has a tragic end.*" There is hardly an animal or a plant, from the humblest protophyte to man himself, that is not subject to the attacks of other organisms. Herbivorous animals feed upon the plants, and these animals in their turn form the food of carnivorous species. Those that escape being devoured in this way, and successfully resist the effects of climate usually at last fall a prey to the inroads of bacteria or other parasites.

Plants are particularly subject to destruction in the early stages of their growth. Darwin dug and cleared a piece of ground three feet long and two feet wide, and then marked all the seedlings of the native weeds as they came up, and out of the 357 no less than 295 were destroyed, chiefly by slugs and insects ("Origin of Species," vol. i., p. 83).

Judd says: "It is not at all uncommon for a crow or blackbird to eat from 30 to 50 seeds of smartweed or bindweed, or a field sparrow 100 seeds of crab grass, at a single meal. In the stomach of Nuttall's sparrow were found 300 seeds of amaranth, and in another 300 seeds of lamb's quarters, a tree sparrow had consumed 700 seeds of pigeon grass, while a snowflake from Shrewsbury, Mass., which had been breakfasting in a garden in February, had picked up 1,000 seeds of pigweed" ("Year Book, United States Agricultural Department," 1898, p. 222). Professor Beal has estimated that in the State of Iowa the tree sparrows alone destroy annually about 1,750,000 pounds, or 875 tons of weed seeds (*l.c.*, p. 226).

These seed-eating birds are in turn preyed upon by the various hawks and owls.

In the sea, plants form the food of few species except the most minute animals. A vast majority of marine species are carnivorous, and the destruction is enormous. Brooks gives a vivid picture of this struggle ("Foundations of Zoology," pp. 220–224 and 231–233). Speaking of the inlets among coral islands he says, "Nothing could illustrate the fierceness of the struggle for food among the animals on a crowded sea-bottom more vividly than the emptiness of the water in coral sounds where the bottom is practically one enormous mouth."

3. *Effect of the Removal of Checks.*—The enormous destruction caused by these checks on population may be realized to some extent if we consider the birth rate.

It may be stated as a general rule that the birth rate in existing species is proportional to the rate of destruction. Thus the petrel, which nests on inaccessible cliffs and has few enemies, produces but one egg at a time. While the lobster, whose young are exposed to the attacks of innumerable enemies from the time they are hatched, produces from 3,000 to 90,000 eggs. (The largest number found by Herrick was 97,440, "The Lobster," p. 51.) A single carrion fly is said to produce 20,000 living maggots. These reach full size in five days, and the pupa stage lasts five days. It has been estimated that a single fly could produce in three months one hundred millions of millions of millions (Wallace, "Darwinism," p. 25). The common mosquito (*Culex pungens*) lays from 200 to 400 eggs in a bunch. These hatch in sixteen hours. Under favorable conditions the larvæ reach the pupa stage in seven or eight days. This stage lasts two days. Thus one pair of mosquitoes may produce 400 adult offspring in less than ten days. In a few days more these are ready to lay eggs in their turn.

According to Merriam, the house sparrow produces annually five or six broods of four to six each. Assuming an average of 24 young per annum, with sexes equally divided, the produce of a single pair in ten years will be 275,716,983,698 ("Agricultural Report," 1886).

The elephant is said to be the slowest breeder of all animals. Yet Darwin has estimated that if an elephant lives 100 years and produces 6 young ones, in 750 years the produce of one pair would equal 19,000,000 elephants. Man is also an extremely slow-breeding animal, yet the human population tends to double in about twenty-five years.

The power of rapid multiplication is perhaps best illustrated by the waves of life that sometimes sweep over a country. Brehm thus describes one of these waves (Brehm, "From North Pole to Equator," 1896, pp. 74–76).

In a description of the fauna of the tundra, or barren lands of northern Siberia, Brehm says: "He (the lemming), or at least his tracks, may be seen everywhere throughout the tundra. The tracks run in all directions, often through places overgrown by dwarf birches, narrow, smooth, neatly kept paths in the moss, going straight for several yards, then diverging to right or left, and only returning to the main path after many circuits. On these we may often see, in great numbers during a dry summer, a little short-tailed, hamster-like animal nimbly pattering along and soon disappearing out of sight. This is the lemming, a rodent smaller than a rat, but larger than a mouse, with a brightly but irregularly marked skin, usually brown, yellow, gray, and black. If we dissect the animal we see, not without surprise, that it consists almost entirely of skin and viscera. Its bones and muscles are fine and tender; its viscera, especially the alimentary and reproductive organs, are enormously developed. This state of things explains some phenomena of its life which were long considered unintelligible; the almost abrupt occurrence of wellnigh unlimited fertility, and the vast, apparently organized migrations of the animal. In ordinary circumstances the lemming leads a very comfortable life. Neither in summer nor in winter has he any anxiety about subsistence. In winter he devours all sorts of vegetable matter—moss-tips, lichen, and bark—in summer he lives in his burrow, in winter in a warm, thick-walled, softly-lined nest. Danger, indeed, threatens from all sides, for not only beasts and birds of prey, but even the reindeer devour hundreds and thousands of lemmings; nevertheless, they increase steadily and rapidly, until special circumstances arise when millions, which have come into existence within a few weeks, are annihilated within a few days. Spring sets in early, and a more than usually dry summer prevails in the tundra. All the young of the first litter of the various lemming females thrive, and in six weeks, at the most, these also multiply. Meantime the parents have brought forth a second and a third litter, and these in turn bring forth young. Within three months the heights and low grounds of the tundra teem with lemmings, just as our fields do with mice under similar circumstances. Whichever way we turn, we see the busy little creatures, dozens at a glance, thousands in the course of an hour. They run about on all the paths and roads; driven to extremity, they turn snarling and sharpening their teeth, on the defensive even against man, as if their countless numbers lent to each individual a defiant courage. But the countless and still increasing numbers prove their own destruction. Soon the lean tundra ceases to afford employment enough for their greedy teeth. Famine threatens, perhaps actually sets in. The anxious animals crowd together and begin their march. Hundreds join with hundreds, thousands with other thousands; the troops become swarms, the swarms armies. They travel in a definite direction, at first following old tracks, but soon striking out on new ones; in unending file, defying all computation, they hasten onward; over the cliffs they plunge into the water. Thousands fall victims to want and hunger; the army behind streams on over their corpses; hundreds of thousands are drowned in the water or are shattered at the foot of the cliffs; the remainder speed on; other hundreds and thousands fall victims to the voracity of Arctic and red foxes, wolves, and gluttons, rough-legged buzzards and ravens, owls and skuas, which have followed them; the survivors pay no heed. Where they go, how they end, none can say, but certain it is that the tundra behind them is as if dead, that a number of years pass ere the few who have remained behind, and have managed to survive, slowly multiply, and visibly re-people their native fields."

Hudson describes a similarly rapid increase of mice on the Pampas of South America, which was finally brought to a close by a drought and the increase of enemies ("Naturalist in La Plata," p. 59, *et seq.*).

This country is subject to periodic waves of locusts and chinch-bugs, which swarm at such times in hundreds of thousands and do enormous damage to crops (Webster, "The Chinch-Bug," 1898). With the introduction of irrigation and forage plants in the far West, the jack-rabbits have increased rapidly and become a pest. In California during the ten years from 1888 to 1897, 494,634 jack-rabbits were killed in "drives," and yet the total number living was not seriously diminished (Palmer, "Jack-Rabbits," 1897).

The power of rapid multiplication is also well illustrated by the effect of introducing animals and plants into a new country. If the climate be favorable, the introduced form, freed from its natural enemies, may often increase amazingly.

Many of our common weeds, like the ox-eye daisy and the so-called Russian thistle, are good examples of this. Wallace gives a number of cases ("Darwinism," p. 28) of the rapid spread of European plants introduced into South America, New Zealand, and other places.

"Columbus in his second voyage left a few black cattle at San Domingo, and these ran wild and increased so much that twenty-seven years afterward herds of from four thousand to eight thousand head were not uncommon. Cattle were afterward taken from this island to Mexico and other parts of America, and in 1587, sixty-five years after the conquest of Mexico, the Spaniards exported 64,350 hides from that country and 35,444 from San Domingo. . . . In the pampas of Buenos Ayres there were at the end of the last century, about twelve million cows and three million horses, besides great numbers in other parts of America." Similar results were obtained by setting free hogs and asses. Camels even, turned loose in Texas not many years ago, increased so rapidly as to become a nuisance.

The common European rabbit has become a pest in Australia and New Zealand. The rabbits were first liberated near Melbourne about 1864, and later in Tasmania and New Zealand. They multiplied so rapidly that in 1879 the legislature of South Australia took action for their destruction, and the matter was taken up soon after in New South Wales, Queensland, New Zealand, and Tasmania. But in spite of all efforts to destroy them, they continued to multiply. Between 1873 and 1898 New Zealand exported two hundred million rabbit skins.

Another example of the rapid increase of an introduced animal is afforded by the Indian mongoose in the West Indies. But at our very doors we have an equally good example in the house sparrow. The first successful importation was made into Brooklyn in 1852. The birds were introduced into Portland, Me., in 1854, and into Providence, R. I., in 1858, some escaping in Boston. Between 1863 and 1870 they were imported into eight cities, one lot of one thousand being sent to Philadelphia. Between 1870 and 1880 it is estimated that the range of this species had been extended by 16,000 square miles (Palmer, 1898), and it has continued to spread. Merriam estimates the rate of spreading of the sparrow as follows ("Agri. Rept.," 1886, p. 238):

	Square miles.
1870-75	500
1875-80	15,640
1880-85	500,760
During 1886	516,500
Yearly average United States and Canada	69,000

4. *Competition.*—These examples will suffice to show how rapidly animals and plants can multiply when the

first two classes of checks on population are not in operation. But this rate of multiplication cannot continue indefinitely. For, finally, food supply will become exhausted or the individuals will become so crowded as to deprive one another of the light, air, or space necessary for life. Thus the tendency of organisms to increase in geometrical ratio, if not held in check by other causes, will ultimately cause a severe competition, and this constitutes the third class of checks on population.

Competition may be between individuals of the same species, or between different species having similar habits. It is well illustrated in the forests, where each tree that reaches its full growth is, according to Pinchot, "the survivor of hundreds (or sometimes even of thousands) of seedlings."

An example where the competition of species has had a marked effect on the flora is quoted by Wallace (pp. 20–22). M. Hansten-Blangsted gives an account of the struggle between the trees in the forests of Denmark. The chief combatants are the beech and the birch, the beech being everywhere successful in its invasions. "Forests composed wholly of birch are now found only in sterile sandy tracts; everywhere else the trees are mixed, and wherever the soil is favorable, the beech rapidly drives out the birch. The latter loses its branches at the touch of the beech, and devotes all its strength to the upper part, where it towers above the beech. It may live long in this way, but it succumbs ultimately in the fight of old age, if of nothing else, for the life of the birch in Denmark is shorter than that of the beech." The superiority of the beech appears to be due to its denser shade. Nothing can live beneath it, while it grows perfectly well under the shade of the birch. The birch has been saved from total extinction only by the fact that it had possession of the Danish forests long before the beech ever reached the country, and that certain districts are unfavorable to the growth of the latter.

But we need not go to Denmark to witness a struggle of this kind. In Virginia, when a field is abandoned, trees soon spring up of all kinds, but the pines by virtue of their more rapid growth and dense shade, soon acquire the ascendancy. Many "old fields" are to be seen there where the furrows of the last crop of corn are still visible, and the ground is covered with a thick growth of young pines. Many of these die while still small, and among them may be found a few slender oaks, chestnuts, and tulip trees. If the pines are cut, or if they are allowed to grow old and fall down with decay, their place is taken at once by the longer-lived and more hardy oaks and chestnuts. So that it is a common saying in Virginia that "oaks follow pines."

Another case in point is an experiment of Darwin's. He marked out a little plot of mown turf, three by four feet, and allowed the plants to grow up freely. The result was that out of twenty species growing there nine perished ("Origin of Species," vol. i., p. 83).

Among animals the birds show especially the effect of competition. In some species each pair requires a certain area for a feeding ground, and drives off all others. The English sparrow is said to be responsible to a considerable extent for the decrease of our native birds, and according to a recent writer in *Nature* (Allchin, January 19th, 1899, p. 271), this same sparrow has had a similar effect upon the swallows and martins in England.

The efficiency of competition in checking increase is shown when the competition is lessened by an enlargement of the food supply. Most of the waves of life that have just been described are due to such an advantage rather than to protection from enemies.

In order to understand the results of these factors in the struggle for existence, it must be remembered that, as a rule, the relations of organisms to one another are highly complex; so that any change in the environment of one species is apt to effect a host of others. Thus, according to Lintner, the English sparrow protects the tussock moth (*Orgyia lincostigma*) by driving away its enemies, the robbin, oriole, and cuckoo, the only birds that can feed upon the hairy caterpillars, and thus the sparrow indirectly injures the elms and other trees ("Agric. Rept.," 1886). The classical example of this is Darwin's one of the relations of cats to the crop of clover seed. He says: "I have also found that the visits of bees are necessary for the fertilization of some kinds of clover; for instance, twenty heads of Dutch clover (*Trifolium repens*) yielded 2,290 seeds, but twenty other heads protected from bees produced not one. Humble bees alone visit red clover, as other bees cannot reach the nectar. Hence we may infer as highly probable that, if the whole genus of humble bees became extinct or very rare in England, the heartsease and red clover would become very rare, or wholly disappear. The number of humble bees in any district depends in a great degree on the number of field mice, which destroy their combs and nests; and Colonel Newman, who has long attended to the habits of humble bees, believes that 'more than two-thirds of them are thus destroyed all over England.' Now the number of mice is largely dependent, as every one knows, on the number of cats; and Colonel Newman says: 'Near villages and small towns I have found the nests of humble bees more numerous than elsewhere, which I attribute to the number of cats that destroy the mice.' Hence it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in that district."

Wallace quotes an example from Sir Charles Lyell. He says: "If, by the attacks of seals or other marine foes, salmon are reduced in number, the consequence will be that otters living far inland will be deprived of food and will then destroy many young birds or quadrupeds, so that the increase of a marine animal may cause the destruction of many land animals hundreds of miles away." Another example of complexity of relations between organisms is given by Darwin: "In Staffordshire, on the estate of a relation where I had ample means of investigation, there was a large and extremely barren heath which had never been touched by the hand of man; but several hundred acres of exactly the same nature had been enclosed twenty-five years previously and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable, more than is generally seen in passing from one quite different soil to another; not only the proportional numbers of the heath plants were wholly changed, but twelve species of plants (not counting grasses and carices) flourished in the plantations which could not be found on the heath. The effect on the insects must have been still greater, for six insectivorous birds were very common in the plantations which were not to be seen on the heath; and the heath was frequented by two or three distinct insectivorous birds. Here we see how potent has been the effect of the introduction of a single tree, nothing whatever else having been done, with the exception of the land having been enclosed, so that cattle could not enter."

These examples are enough to show how very complex are the relations of organisms to one another. We see how a change in the environment of the salmon produces a change in the environment of land animals far away, and how the introduction of a single tree and the exclusion of cattle profoundly affect a host of other organisms. This gives some idea of the complexity of the phenomena to be considered in a discussion of the origin of species.

Natural Selection.—The facts of variation, inheritance, and the struggle for existence lead, as Darwin and Wallace pointed out, to the *a priori* assumption of the theory of natural selection. If individuals differ in their characteristics, and if there is a struggle for existence in which many perish, then there may be a correlation between the death rate and certain structural or physiological peculiarities, that is, we shall have a survival of the fittest, or better, an elimination of the least fit. But in order that new species may result, not only must the favorable peculiarities of the survivors be transmitted to future generations by inheritance, but other conditions must be fulfilled which we will now consider.

In the first place, as indicated in the preceding paragraph, it by no means follows that there is any necessary relation between destruction and any structural or physiological peculiarity. A flood, a tornado, a forest fire may destroy all in its path. In such a case the destruction is purely fortuitous, or non-selective. On the other hand, if a number of persons are exposed to an infection, say typhoid, to which they present different degrees of susceptibility, then those which possess those physiological characteristics that give susceptibility to the disease in the greatest degree will be those that die, and we shall have then a *selective death rate.* It may be noted in passing that a death rate which is selective in regard to one character may be fortuitous in respect to another, unless the variations of the two characters are correlated.

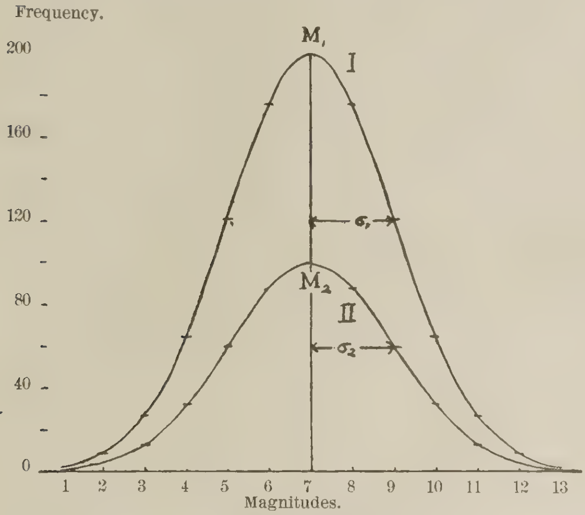

Fig. 1947.—Fortuitous Destruction of 500 in 1,000, Normal Curves. *I*, Birth curve; *II*, survival curve.

Let us consider now what the effect of these two kinds of destruction would be upon the curve of variation. Where there is no destruction, and all that are born survive, we may call the curve the *birth curve,* and its mean the *birth mean.* While the curve obtained after destruction had taken place would be the *survival curve,* and its mean, the *survival mean.* Now the effect of purely fortuitous destruction would be to give a survival curve that would be exactly like the birth curve except that it would be flatter, and the birth mean and the survival mean would coincide. Such a case is illustrated by Fig. 1947, where the upper line (*I*) may be taken to represent the birth curve of say a thousand individuals in a certain locality, and the lower line (*II*) would be the curve after a fortuitous destruction of half the number. (If percentages were used instead of absolute numbers, the curves would be exactly alike.)

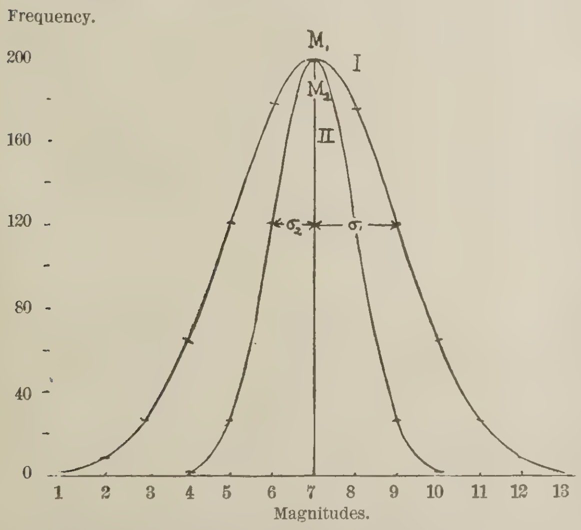

Fig. 1948.—Selective Death Rate of 500 in 1,000 when the Birth and Survival Means Coincide, Normal Curves. *I*, Birth curve; *II*, survival curve.

The effect of a selective death rate upon the birth curve would depend upon whether the cause of death is a constant factor of the environment or a new one. If it be a constant factor, it is probable that the species has become adjusted to it. In this case the most favorable variation of any character affected by this condition will be represented by the mode, and probably the mean, of the birth curve. Elimination will cause a decrease of variability, so that the survival curve will be steeper on the sides than the birth curve (Fig. 1948). But the position of the mean will not be changed, and there will be no evolution. On the contrary, the effect of natural selection here will be, if anything, to make the species more stable.

It is only when the species as a whole is not adjusted to the cause of death that we may expect natural selection to produce evolution. Then the birth mean will not coincide with the most favorable variation, and the effect of elimination will be to decrease the variability to a greater extent upon the less favorable side than on the other and thus to shift the mean, as in Fig. 1949. This is a purely imaginary example, where the most favorable value of the character measured is supposed to be 9. It will be noticed that the effect of elimination here has been to shift the mean from 7 to 7.88, that is toward 9, and the variability is decreased as shown by the smaller value of the standard deviation, σ_2, which is 1.46 instead of 2. The survival curve is also skew, while the birth curve is supposed to have been symmetrical.

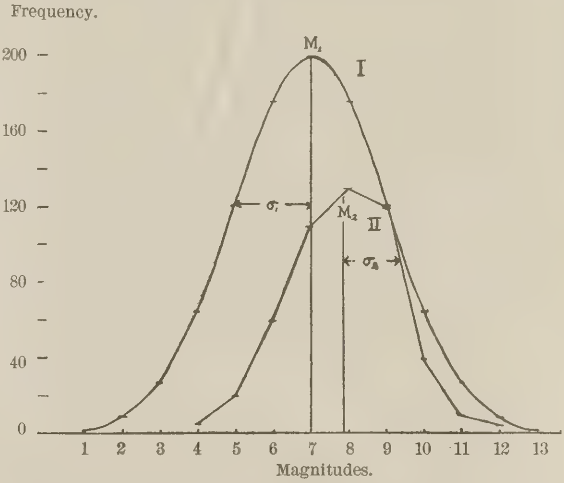

Fig. 1949.—Selective Death Rate of 500 in 1,000 where the Birth and Survival Mean do not Coincide. *I*, Birth curve, normal; *II*, survival curve, purely imaginary.

So far we have dealt with the effect of selection upon the first generation only. Of course, fortuitous destruction will have no effect upon the type or variability of the next generation, for the type and variability of the parents have remained unchanged. A selective death rate symmetrical on both sides of the birth mean will not affect the type and will have but a slight effect upon the variability, for Pearson has shown that selection for an indefinite number of generations cannot reduce the variability more than eleven per cent. But where the most favorable value of a character does not coincide with the birth mean, then there will be a change of type, the rapidity of change depending upon the severity of the selection. From the law of ancestral heredity Pearson has calculated the probable effect of perfectly rigorous artificial selection. His results are given in a table, from which it is possible to calculate the curves of six successive generations where the parents selected have a given deviation from the original mean of the population. Fig. 1950 illustrates such a case, where the mean of the population is represented by $M = 0$, the standard deviaiton is $\sigma = 1$, and the parents for each generation are supposed to have the selected character of the value $H = + 2$, or twice the standard deviation. Then the average deviation of the first, second, third, etc., generations of offspring from the original mean of the population will be represented by the distance from M to the ordinates h_1, h_2, h_3, etc. It will be seen that the regression becomes less in each generation until, in the sixth, h_6 almost coincides with H. In other words, if it were possible to make this rigorous selection, we might expect at the end of the sixth generation to obtain a new race that would breed true about a mean differing very little from the selected value.

Turning now from *a priori* considerations to observed facts, what evidence is there that natural selection has actually been a factor in evolution?

First, there is the observed fact of a selective death rate. To say that where the death rate depends upon individual peculiarities the fittest will survive in the struggle for existence, is a truism, for our only means of judging of fitness is the ability to survive. While a great deal has been written upon the subject, exact observations have only just begun to be made. It is not often easy to find a correlation between structure and the death rate. Only two instances are on record.

From measurements made by Thompson and himself in successive years, Professor Weldon came to the conclusion that in the crabs, *Carcinus mænas*, in Plymouth Harbor, England, the frontal breadth of the carapace was becoming narrower from year to year. Seeking a cause for this he found it to be probably the increase of sediment in the harbor, due to the building of a breakwater, which hinders the flow of the tides. To test this theory, he placed a number of crabs in aquaria with a considerable quantity of china clay, like the silt in the harbor, suspended in the water. A number of crabs died, and at the end of the experiment the dead crabs were separated from the living, and all were measured. It was found that the survivors had distinctly less frontal breadth than the dead crabs.

If this selective destruction is continually going on in the harbor, then the crabs protected from the action of the silt during a portion of their lives should show a greater average frontal breadth than the wild crabs of the same age. A number of crabs were kept in aquaria with clean sea-water until they moulted. When the shell was hard they were killed and compared with wild crabs of the same age. It was found, as expected, that the frontal breadth of the protected crabs was greater.

The great storm of February, 1898, enabled Bumpus to study a similar case among the house sparrows (*Passer domesticus*). During the storm in Providence 136 birds were picked up in a helpless condition. When brought into the laboratory 72 of these revived and 64 died. A number of measurements were made upon each bird of the two lots, and it was found that the mean of surviving birds differed perceptibly in many dimensions from the corresponding mean of the dead ones. Moreover, the dead birds showed a greater average deviation from the mean than the surviving ones.

In these cases single characters were studied in relation to the death rate. It would be more to the point if we could correlate the sum of the peculiarities of the individual as a whole with his chances of death, for natural selection acts upon whole individuals, not upon single characters. Pearson has demonstrated a very ingenious method of doing this for man. If there were no natural selection, the whole death rate would be non-selective, fortuitous; on the other hand, natural selection would reach its maximum efficiency when the death rate becomes wholly selective. In nature the death rate would be usually partly selective and partly non-selective, and the problem is to determine what proportion of the total death rate is selective. In Pearson's method "no attempt is made to select any particular organ, but we take pairs of individuals having some general resemblance in their whole complex of organs and characters, and correlate their fitness for surviving under practically the same conditions of life. Now pairs of relatives or members of the same family are precisely such individuals. If there were no selective death rate there would be no correlation between the ages at death of, say, brothers. On the other hand, if there were no non-selective death rate we might reasonably suppose duration of life would be determined by the law of ancestral heredity," and we should expect the correlation between the durations of life of pairs of brothers to be the same as that observed in the case of stature and other characters.

From a study of one thousand pairs of brothers recorded in the peerage Pearson found that of the total death rate eighty per cent. was selective. Comparing fathers and sons, the result was sixty-five per cent. Natural selection, then, is by no means inoperative at the present time in the human species.

The second line of evidence is one that especially meets the objections of the advocates of the theory of special creation. This is that it is impossible to find throughout the whole range of the animal and vegetable kingdoms a single structure or function developed in one species for the exclusive benefit of another.

Darwin regarded this point as of so great importance that he offered to give up his whole theory if it could be proved in a single case that a structure or instinct is developed in one species for the exclusive benefit of another. To be sure, there are innumerable cases in which the characters of one species are of use to another; but this value to the other species is purely secondary. For example, the nectar of flowers forms the daily food of bees, but this nectar is primarily of use to the plant in securing the visits of the bees, and thus providing a means for the transportation of the pollen and cross fertilization. As the result of thoughtful search Romanes was able to discover only two cases that appear to be exceptions to this rule. It is well known that the aphides (green plant lice) secrete a sweet juice that is much sought after by ants. So far as we know, this secretion is of no value to the aphid. But it has not yet been investigated suffi-

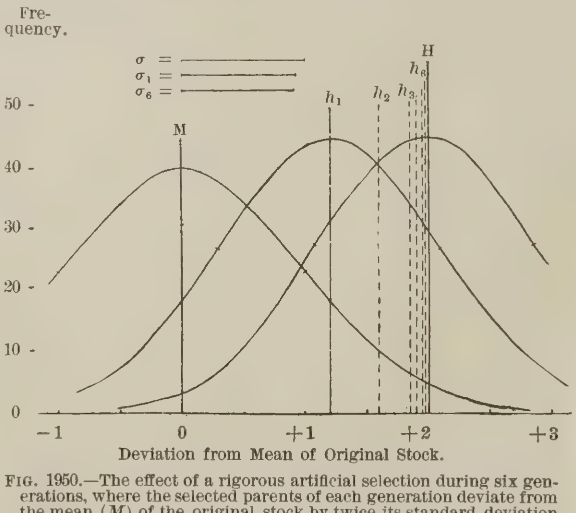

FIG. 1950.—The effect of a rigorous artificial selection during six generations, where the selected parents of each generation deviate from the mean (M) of the original stock by twice its standard deviation (H). The broken lines h_1 h_2 h_3 . . . h_6 represent the position of the means of the first, second, . . . and sixth generation of offspring. When $M = 0$ and $H = 2$, $h_1 = 1.2$, $h_2 = 1.6$, $h_3 = 1.85$, $h_4 = 1.90$, $h_5 = 1.94$, $h_6 = 1.97$. The curves of frequency are drawn for only M, h_1 and h_6, and their standard deviations are $\sigma = 1.0000$, $\sigma_1 = 0.9055$, $\sigma_6 = 0.8944$. (Data from Pearson.)

ciently to show that it is of no use. It may be a means of removing waste products of metabolism. Moreover, it seems to be rather more of a luxury than a necessity for the ants. The other case is still more remarkable. It is the production of galls upon plants as the result of the growth of an insect larva within the tissues of the plant. The gall forms a perfect home for the larva, and differs in character, not only in different plants, but it differs also according as it is produced by one species of insect or by another, each species of insect having its own peculiar form of gall. All grades are found, from simple cysts, hardly worthy to be called galls, to structures which are extremely elaborate. Here we have a structure developed by a plant apparently for the benefit of an insect. But, as pointed out by Romanes, the gall arises as a reaction on the part of the plant to a poison produced by the insect, and its first appearance was probably due to one of those accidental effects of an injurious substance upon an organism, such as Herbst discovered when he treated sea-urchin larvæ with potassium and lithium salts. The gall-forming property, being of use to the insect, would be preserved and modified by natural selection acting directly upon the insect, and the plant would be affected indirectly.

The third line of evidence is that which first attracted Darwin's attention to the principle of selection. Darwin found that in the production of domestic varieties of animals and plants artificial selection is the keynote to success. All of our domestic productions are descendants from wild species, but in many cases either the wild parent species has been exterminated, or else the domesticated descendants have been so greatly modified that it is impossible to recognize the ancestral form. The differences between artificial varieties and between them and the original form, when known, are often as great as the differences between species, or even between genera, of animals and plants in the natural state. Compare a deer hound with a King Charles spaniel, a Cochin China with a game cock, a pouter pigeon, a fan-tail, and the wild rock dove, from which Darwin showed the pigeons to be descended. Romanes calls special attention to the well-marked varieties of canary birds, and regards this as a case of unusual interest because of the shortness of time during which the evolution has taken place, the first mention of these birds that he could find being by Gesau in the sixteenth century. Among most of our domestic animals man has been selecting more or less unconsciously the individuals which best served his needs or answered to his ideal of beauty; and this has been going on since prehistoric times. In later years selection has been practised with great care and with reference to more exact ideals, and the progress made is truly wonderful.

Darwin regarded evolution as an extremely slow process, and this idea prevailed for a long time, but recently several cases of very marked change in domestic forms have come to light where the change has been comparatively rapid. The American trotting horse is a case in point. An ordinary horse runs when he wants to move rapidly, but the trotting horse prefers the trot, and will keep to that gait until he attains a speed far beyond that at which other horses would be forced to break into a gallop. The lowest limit of what is regarded as racing speed in a trotting horse is a mile in two minutes and thirty seconds. The first horse to make a mile within 2:30 was Lady Suffolk, a great-granddaughter (by three crosses) of Messenger, a thoroughbred race horse imported from England in 1788, and famous as the ancestor of almost all American trotting horses. Lady Suffolk was foaled in 1833, and made her record in 1845. From that time the speed of the fastest trotter has steadily increased, until Cresceus, foaled in 1894, made the remarkable record of 2:02¼ in 1901, beating the record made by The Abbot the previous year. But the improvement of the trotting horse is seen best when we compare the number of fast trotters at a recent date with the number several years before. In 1892 there were 116 horses with records of 2:15 or better, at the end of 1897 there were 585 horses with such records, and during 1897 109 horses entered this class, only 7 less than the total number in 1892, and many of these had no previous record.

Now is this improvement due to the selection of fortuitous congenital variations, or to some other cause? If races are changed by the inheritance of acquired characters, this process should be expected to be efficient in the case of the trotting horse. This question will be discussed later when we consider the inheritance of acquired characters as a factor of evolution. But it may be said now that, of the sixteen champion trotters from Lady Suffolk to Cresceus, Cresceus is the only one having a sire with a record below 2:30, and The Abbot is the only one that has a dam with any record at all, and it seems probable that a careful study of the pedigrees of trotting horses will fail to show that horses which have been trained have any greater power of transmitting trotting speed than horses which have not been trained. It is probable that such a study will show that that combination of instinct and structure which enables a horse to trot at a high speed has arisen as a fortuitous variation in a few individuals, and that fortunate selection and crossing of their descendants during eight or ten generations at most has produced the remarkable result that we see to-day. This is the more probable since Galton has shown that variations in speed follow the normal curve. Take the pedigree of Alix, for example. Both parents of this champion trotter were totally untrained. Her paternal grandsire has a record of 2:21¾, the others have no record. Of her grandparents only one has a record (2:21½), and of her great-grandparents again only one has a record (2:42). On the other hand, her descent is traced by more than fourteen converging lines from Messenger, the ancestor of Lady Suffolk. She is descended by four lines from imported Bellfounder, the son of a Norfolk trotter, and by four lines from Amazonia, a "natural trotter." Moreover, she counts among her ancestors the sires of three champion trotters: Dexter, 2:17¼; Goldsmith Maid, 2:14, and Maud S., 2:08¾, and if each ancestor be regarded as a separate individual at each place in which he occurs in her pedigree, it will be found that she is descended from seven sires of champions, three on the paternal side, and four on the maternal side.

But if the inheritance of acquired characters may be a factor in the development of the trotting horse, there are other cases of rapid improvement in which it cannot have entered. One of these, the cultivated cyclamen (*Cyclamen latifolium* Sibth.), is one of the spring wild flowers in Greece and Syria. It has pink flowers with a ring of darker color at the throat (W. T. T. Dyer, *Nature*, May 20th, 1897, vol. lvi., pp. 65–68). The species is said to have been first cultivated in Europe at Lille in 1731. It was probably obtained from Syria. "The Lille plant ultimately went to Ghent, and it has been asserted that all the cultivated forms in existence are descendants from this one individual." A variety with white flowers —"pure white with a bright purple button"—was described in 1768. The modern development of the plant began in 1860, and started with one of the principal growers (Messrs. Sutton) with the old "crimson and white."

The changes have been brought about entirely without resort to hybridization. But starting with the slightest deviation, even so small as the slightest difference in a cotyledon of a germinating seed, by careful self-fertilization and selection the present varieties have been produced. The changes produced have been in the size of the flower, its fragrance, color, and form of corolla. The original form has narrow, twisted, reflexed petals about an inch long. The cultivated varieties have broader, less twisted petals, and in one variety they have reached a length of three inches. This was accomplished by continuous in-breeding and selection. The old crimson and white had a crimson ring at the throat, but was otherwise an albino. From this, forms have been produced varying from pure white, on the one hand, to a uniform deep crimson, on the other. "The modern colored forms were obtained in the first instance by selecting forms in which the colored ring showed a disposition to spread into the white corolla segments. The first indication would be a scarcely perceptible streak. By selection from self-fertilized plants the streak was widened into a stripe. Continuing the process, the stripes united, and a uniformly colored flower was obtained." The colored varieties when self-fertilized come true from seed.

One of the most remarkable modifications in the form of the corolla is the spreading of the segments. Cyclamen belongs to the order *Primulaceæ*, and is distinguished from the rest of the tribe *Lysimachiæ*, to which it belongs, by the reflexed segments of the corolla. In the variety with a spreading corolla, then, we see a modification of a character which not only distinguishes the species but also the genus.

Doubling has occurred in one variety. Ordinarily doubling is due to a homœotic variation of the stamens by which they become petal-like. In this case, on the other hand, the stamens retain their proper structure, and both they and the segments of the corolla become increased in number.

The butterfly form is a case of parallel variation, it having been obtained independently by several horticulturists. In this variety the petals are partly spreading and arched, and are toothed and curled at the edges. It is interesting to note that in one case at least there is a correlation between the corolla and the leaves, for they also are toothed. This variety arose as a well-marked sport which was improved by selection.

Another example of the rapid effect of selection is the tomato. The different varieties of the edible tomato (*Lycopersicum esculentum*) differ as much, if not more, than do the other species of the genus (Bailey, "Survival of the Unlike," pp. 112–125). Colonel Waring, who introduced the Trophy tomato in 1872, gives the history of this variety, from which the best modern tomatoes have been produced. The Trophy tomato was the result of crossing and selection begun by Dr. Hand, of Baltimore County, Md., in 1850. He began by crossing the smooth "Love Apple," which was filled with juice and seeds, with the common convoluted red tomato of that period, which was so rough as to be unfit for use. It consisted practically of four or five separate fruits packed together in one, with the skin running far into the convolutions. After several years by continued in-breeding and selection he succeeded in producing a form which combined with the smooth skin of the Love Apple the solid fleshy mass of the compound red. This accomplished, he continued to select a very few specimens of the best and best flavored of the earliest fruit for the next year's seed, and thus increased the size and solidity of the fruit, until in 1870 he had produced a variety which was a mass of flesh interspersed with ten or more small seed cells, and which was the earliest, largest, smoothest, the most fleshy, and much the best flavored of all the kinds then grown. Moreover, the continued selection had resulted in a marked fixity of type, which was very different from the two- or three-celled original form.

The growth of sea-island cotton, on the islands off the coast of South Carolina and Georgia, was made possible only by the process of selection. When first introduced from the West Indies, the plants were not adapted to the climate, and seldom produced fruit. But by rigorous selection a race was produced which was well adapted to the climate, and the quality of the fibre was improved until now it is the best grown in any part of the world. That the improvement in the fibre is due to selection and not to conditions of growth is shown by the fact that when selection is relaxed the fibre deteriorates (Webber, "Year-Book Dept. Agric.," 1898, p. 358).

Many more examples might be cited to show how great the changes are that have been produced by artificial selection. Many domestic races produced in this way differ as much from each other and from the parent species as do species or even genera in nature. If artificial selection acting during only a few generations can produce so great changes, how much more effective must have been natural selection, which is probably much more rigorous and continuous, acting through countless ages.

To sum up, then, we have considered three lines of evidence that natural selection is a factor in organic evolution: 1. We have observed facts of the struggle for existence and a selective death rate. 2. We find that no organism in nature has developed any structure or function for the exclusive benefit of another species, contrary to what we might expect to find on the theory of special creation; but just what must be the case on the theory of natural selection. (This would probably be true also on any theory of evolution.) 3. We find that the analogous process of artificial selection has been the most effective means of developing in domestic races those qualities of most value to man, and therefore we infer that natural selection has been an important factor in developing in natural species those qualities of benefit to themselves.

One of the best ways of testing a theory is to attempt to apply it to concrete cases of the class of phenomena which it is supposed to explain. In the applications of the theory of natural selection we shall find the fourth and last line of evidence in favor of the theory.

The phenomena in question are in general those of *adaptation*. Many plants have especial floral structures which facilitate cross fertilization by the aid of insects, and Darwin has shown that this is of great advantage to the species. Climbing plants have peculiar structures and powers of movement that are clearly of advantage in enabling the long, slender stems to find support. Both plants and animals frequently have structures which serve to repel enemies, and many animals are provided with a protective coloring which renders them inconspicuous to their enemies or to their prey. Other animals, provided with offensive secretions or weapons, also have conspicuous warning colors which render them less liable to attack. Finally, there are inoffensive animals which resemble the offensive ones superficially in color and form, and by this mimicry probably share in their immunity from enemies.

These are examples of a large and important class of phenomena that, rejecting the theory of special creation, can be explained by only one theory of evolution, that is the theory of natural selection. Thus we see that natural selection is not merely a factor, but is perhaps the most important of all factors in organic evolution.

Passing over the objections to the theory of natural selection that arise from misunderstanding of the theory or ignorance of the facts, there are three objections that are important.

First, it is true that a great many species are distinguished by differences of form or color that are so minute that it seems impossible for them to be of selective value. Not knowing all the conditions of life, we are unable to say that such differences are not in themselves of selective value or correlated with characters of selective value. But in many cases there is no evidence of such value or correlation.

Second, one of the most marked peculiarities of species is infertility when crossed with other forms. Now it is difficult to see how infertility of any form could be produced by natural selection, except in relation to the food supply. But food supply could have nothing to do with infertility between species.

Third, a distinction must be drawn between linear evolution and divergent evolution. Linear evolution would be the gradual change of specific type by which the new species would become different from the old, but the number of species would remain the same. Divergent evolution, on the other hand, would mean the splitting of original specific types into two or more new types. Now it would be impossible for a species to become multimodal and ultimately to separate into two or more by the action of natural selection alone. For there would be nothing to prevent individuals of different types from breeding together and thus reducing them all to a common type.

These objections are valid, unless some other factor may be brought to the aid of natural selection. But selection is not the only means employed by the breeder of domestic races; then why should natural selection be supposed to be the sole factor of organic evolution?

Isolation.—When a breeder wishes to improve a race or to create a new one, he not only makes a very careful selection of his breeding stock, but he builds a fence around it and guards it against admixture with other stock. That this principle of isolation, or segregation, is of great importance as a factor of organic evolution has been pointed out, especially by Gulick and Romanes. By isolation is meant "simply the prevention of intercrossing between a separated section of a species or kind and the rest of that species or kind." Romanes regards natural selection as a prime factor of vast importance in evolution, but he believes it to be less fundamental and of more limited application than the principle of isolation. He says: "Equalled only in its importance by the two basic principles of heredity and variation, this principle of isolation constitutes the third pillar of a tripod upon which is reared the whole superstructure of organic evolution."

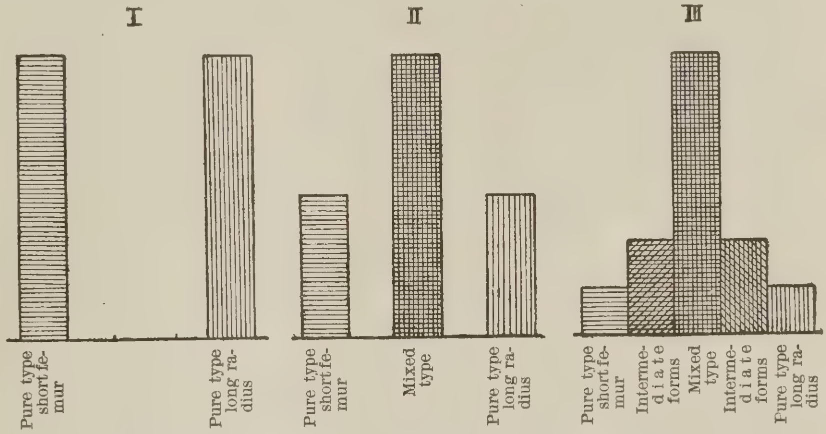

FIG. 1951.—Illustration of the Swamping Effect of Inter-crossing. *I*, First generation—selection intense, model type destroyed leaving two pure types distinctly differentiated; *II*, Second generation—random mating of the two pure types of equal fertility. Results, mixed type twice as numerous as either pure type. *III*, Third generation—random mating of the second; all individuals equally fertile. Results, mixed type six times as numerous, and intermediate forms four times as numerous, as either pure type. (Data from Pearson.)

From this point of view natural selection becomes a special case of isolation, where the individuals best fitted for their environment are isolated and prevented from crossing with inferior individuals by the death of the latter. But, as we have seen, this form of isolation can produce only linear, or monotypic, evolution, for of the two separated sections of the species only one survives. It is possible, however, that the modal type might become the least favorable, and that selection would result in the separation of two types equally fit. To borrow an illustration from Pearson, suppose a short femur and a long radius to be equally favorable and their combination in one individual so rare as to be negligible. Rigorous selection would produce two pure types, as in Fig. 1951, I. But natural selection alone is powerless to prevent the free intercrossing of these types, and the birth curve of the next generation will have the form of II in Fig. 1951. Selection will need to be repeated with equal rigor, otherwise in the third generation we shall find an approach to the normal curve with the mixed type as the mode, six times as numerous as either pure type (Fig. 1951, III). By natural selection alone, then, we should have in such a case merely periodic selection and no progress in divergent evolution. In order that the types A and B may become the foundation for two new species, some other barrier must arise between them. We must look for some other form of isolation.

Isolation may be total or it may be partial of various degrees. A more important distinction is between isolation that is "discriminate" and that which is "indiscriminate." Indiscriminate isolation allows free intercrossing of all variations, or *apogamy*; while discriminate isolation allows only individuals having some point of resemblance to breed together, or *homogamy*.

Apogamy will occur only where sections of the species contain large numbers of individuals at the time of separation. In this case there will be no change of type unless the separated sections become subjected to different conditions so that natural selection may act in a different manner.

Where the isolated section is so small as not to be a fair sample of the population, there will be a sudden change of type. That is, the mean of this section will differ somewhat from the mean of the species as a whole, and there will be a certain degree of homogamy. But this change of type may be very small, and it is very doubtful if homogamy without natural selection can produce any continuous change of type, although Gulick and Romanes have held that it can.

Geographical isolation has, without doubt, played a very important part in the differentiation of species. As we have seen, it will give rise to homogamy or apogamy, according to the number of individuals separated. But probably its most important effect has been to allow the gradual adaptation of parts of a species to different conditions, which would be impossible where free intercrossing could take place.

There are numerous forms of homogamy. "When, for example, any section of a species adopts somewhat different habits of life, or occupies a somewhat different station in the economy of nature, homogamy arises in that section." In plants differences in times of flowering, in habitat, or in the habits of insect visitors may give rise to homogamy. But, according to Romanes, aside from natural selection, the most important form of homogamy is sexual incompatibility, which he calls physiological isolation. In this form of isolation individuals having some peculiarity of the reproductive organs are prevented by this from crossing with individuals having some other peculiarity. If this sterility between different sections of the species be correlated with other peculiarities, we have what Romanes calls *physiological selection* and the formation of a new race, which is free to develop independently of the rest of the species.

This theory is based upon two principal considerations: (1) the general variability of organisms, including the reproductive organs, and (2) the fact that the character that chiefly distinguishes species from varieties is sterility between them. This sterility may be absolute, or it may result in the production of more or less sterile hybrids. Whether sterility has arisen before or after other divergent characters, it will be, in either event, an important factor in evolution. We must suppose it to have arisen gradually and to have spread until it affected a number of individuals; but it is difficult to see how this could have taken place without the aid of some other form of isolation.

The chief evidence for the theory of Physiological Selection is found in the topographical distribution of plants. Naegeli found ninety-five per cent. of allied species and a great number of allied varieties living together in the same stations separated by no barrier except sterility. And this is confirmed by the experiments of Alexis Jordan, published in 1873. He discovered in plants great numbers of varieties hitherto overlooked owing to the minuteness of the differences between them. And he found that in many hundreds of cases these varieties, in nature living side by side, would breed true to seed and be sterile *inter se.*

Sexual Selection.—Another series of special cases of isolation is furnished by the various kinds of sexual selection. This term, as recently employed by Pearson, includes all forms of *selective mating.* This is sharply contrasted with *pangamic mating,* or the mating at random of all members of the race. The forms of selective mating are classified by Pearson as follows:

1. Autogamic mating, or self-fertilization, including the fertilization of a flower by another flower on the same plant.

2. Endogamic mating, or mating within the family, brood, or clan, a very effective mode of isolation.

3. Homogamic, or assortive mating, the union of like with like, the two mates not necessarily being of the same brood.

4. Apolegamic (from *ἀπολέγω,* I pick out, refuse), or preferential mating. This is *sexual selection* in the sense in which the word was originally used by Darwin.

5. Heterogamic mating, or the union of unlikes. Darwin found many cases of this form of mating in his study of the effects of cross and self-fertilization in plants. It includes those cases in which the species is polymorphic and a union of diverse forms is prepotent over a union of similar individuals.

The theory of sexual selection in the narrower sense was devised by Darwin to account for the origin of certain secondary sexual characters in animals.

There are many species in which the individuals of one sex, usually the male, fight with one another for the possession of mates. The fur seal is an excellent example. In such cases it is obvious that those males having superior weapons and strength to use them will beget the greater number of offspring, and that these will inherit and transmit their favorable peculiarities. This might be regarded as a special form of natural selection.

But there are many species, especially among the birds, in which the contest for mates is carried on by gentler means. In these cases the males usually seem to vie with one another in an attempt to excite the sexual instincts of the females by melodious song and cries, by movements of the body, or display of bright colors. It is supposed that those males which are most attractive to the females will produce the most offspring, and thus the development of ornamental secondary sexual characters is regarded as due to selective action on the part of the females.

Of course, this theory can apply only to animals of a relatively high grade of organization, and the efficiency of this factor in evolution has been denied entirely by Wallace and others.

To enter into this controversy would require too much space. But it may be pointed out here that (1) males are frequently distinguished, not only by bright colors, but by a highly decorative color pattern, sometimes associated with a highly elaborate structure, as in the peacock, angus pheasant, bird of paradise, etc.; (2) many birds possess not only call notes, but a melodious song, often to our ears, at least, of great beauty, as the wood thrush, the wren, and the catbird; (3) and, finally, the deer family possess handsome arborescent antlers that are highly ornamental, but certainly less efficient weapons than the straight horns of the antelopes. Now these facts cannot be explained by the assumption of vigor of the male, nor by the usual process of natural selection, while they are easily explained on the theory of preferential mating.

In order that the choice of the female may be an efficient factor in evolution there must be a certain general tendency in one direction. In order to discover whether this be true or not it would be necessary to resort to careful statistical inquiry.

Pearson has pointed out the method for making such inquiries, and in the case of man he found no evidence of preferential mating in respect to stature, but he found distinct evidence of preferential mating in the matter of eye-color or of some closely allied character in the male. The general tendency is for the lighter-eyed to mate, while the dark-eyed are less frequently mated. He concludes that it cannot be doubted "that sexual selection in the form of preferential mating is not a mere hypothesis, but can be demonstrated to actually exist in the case of man."

Preferential mating would have an effect on evolution similar to that of natural selection. That is, there might be a tendency to progressive change of type, but it could not alone produce differentiation. On the other hand, it is clear that self-fertilization and endogamy would aid differentiation, and assortive mating would also have this effect, if mating of this kind takes place.

Pearson, using the method of correlation, studied the stature of one thousand pairs of husbands and wives, and the eye color of seven hundred and seventy-four pairs. And he found that, "the assortive mating is indeed so great that husband and wife have for the average of these two characters a sensibly greater degree of resemblance than that assumed on theoretical grounds to hold for first cousins and approaching the degree of resemblance found for uncle and niece."

Panmixia.—The presence of vestigial organs in vast numbers of species, and the fact that some groups entirely lack organs possessed by other related and perhaps lower groups, as, for example, the snakes, lead to the belief that in the course of evolution organs in many cases have dwindled in successive generations, and sometimes have entirely disappeared.

Perhaps the most natural explanation of these facts would be to ascribe them to the inherited effects of disuse. But this explanation is inadequate, for it will not account for the loss of parts in plants, nor for the loss of passively protective structures in animals; and it is particularly inapplicable to the cases of the loss of wings in neuter insects, for neuters produce no young, and hence there could be no inherited effect.

To meet this difficulty Weismann introduced the hypothesis of *panmixia.* This is merely random mating without selection. But, as has been pointed out by C. L. Morgan and Pearson, the only effect of panmixia would be a reduction from the survival mean to the birth mean. There would be a sudden slight change of adult type in one generation, and after that no further effect.

So it would seem that we must fall back upon Darwin's principle of natural selection and economy of growth. For example, in the case of wingless insects inhabiting small oceanic islands, it is evident that if the species were unable to become strong fliers, it were better for them not to fly at all. Because weak fliers would be apt to be blown out to sea and lost. Darwin argued also that useless organs require as much nourishment as useful ones, and in time of dearth the animal which had to find nutrition for the smallest amount of useless tissue would stand the best chance of surviving. This might account for the dwindling of useless organs, but it would not account for their complete disappearance. For it cannot be supposed that the presence or absence of a minute vestige of an organ could ever be a matter of life or death. And as no satisfactory hypothesis has been advanced to explain this, we shall have to regard it as one of the unsolved problems of evolution.

Bathmic Evolution.—Palæontologists have asserted that they find in the study of extinct animals evidence of a constitutional tendency toward variation in a definite direction. Such a change of type, due solely to something inherent in the constitution, without action of organic or inorganic environment, is called *bathmic* evolution (from *βαθμίς,* basal).

The evidence that such evolution has taken place is not very convincing. Nevertheless, supposing it to be a fact, many explanations have been offered to account for it. Mivart suggested an innate tendency, and Naegeli, a perfecting principle. But these are merely words and explain nothing. Hyatt from a study of certain fossil mollusca, ammonites, found evidence of a cycle of development of species corresponding to the cycle of individual development. He holds that there is a law of growth which compels species to pass through the stages of youth, maturity, and senescence. This may be true of the ammonites; it may be the reason that they are extinct. But it has not been shown to hold for any other group, and the law itself would need explanation.

Weismann has offered as an explanation of bathmic evolution his hypothesis of *germinal selection*. But this is a pure assumption based upon Weismann's theory of the structure of the germ plasma, which is directly contradicted by observed facts (see *Heredity*).

The first reasonable hint of a cause for bathmic evolution has been furnished by Pearson in his theory of *reproductive*, or *genetic, selection*. From the study of four thousand three hundred and ninety families in the middle and upper classes, Pearson found that variations in fertility do not follow a normal symmetrical curve, but have a very skew distribution, small families being much more numerous than large ones. The result is that twenty-five per cent. of the parents produce fifty per cent. of the children. It is clear that on the average one pair of the smaller group of more fertile parents will have as much effect on the type of the next generation as three pairs of the larger less fertile group. Therefore, if fertility be inherited, and if there be a correlation between fertility and any other character, progressive change of type may take place by a purely bathmic process, unless checked by natural selection or other cause. As to the inheritance of fertility, Pearson found from a comparison of the sizes of the families of a thousand pairs of mothers and daughters, where the marriages had lasted fifteen years or more, that there was very good evidence of such inheritance. (He obtained a coefficient of heredity of .213 with a probable error of ±.020.) Similar results were obtained by the study of one thousand pairs of paternal grandmothers and granddaughters. Here the coefficient of heredity (.112 ±.021) is about half as large as for mother and daughter, as would be expected by the law of ancestral heredity, and this is an example of the transmission of a female character through the male line with undiminished intensity. Thoroughbred horses also furnished evidence that fecundity is inherited between dam and daughter and also through the male line, fecundity being transmitted by a sire from his dam to his daughter. There is also evidence of correlation between fertility and other characters. In man, Pearson found that the more fertile women are slightly taller than the less fertile, and dark-eyed fathers and mothers are found to be more fertile than those with light eyes.

Poppies have radiating ridges on the upper part of the seed capsule, the stigmatic bands. In 4,443 capsules of Shirley poppies the range of variation was from 5 to 19 bands and the modal number was 13. Capsules with 12 to 13 bands were found to be very full of seed, while there were hardly any in capsules having very few or very many bands. Likewise in 3,212 seed capsules of *Nigella hispanica* the range of variation in the number of segments was from 2 to 20, with 8 for the modal number. Capsules with 8 segments were found to be very fertile, while those with 10, 11, and 12 segments contained hardly any seed, and those with 5 or less were practically sterile.

It is evident, then, that where the most fertile character coincides with the modal character, as in the case of the poppies and Nigella, this differential fertility, or genetic selection, will tend to preserve the stability of the race, and in order that differentiation of type may take place, this effect will have to be overcome. On the other hand, if the most fertile character differs from the modal character, as appears to be the case in the eye color of man, then there will be a progressive change, unless this is checked by preferential mating, natural selection, or some other cause. So differential fertility is to be reckoned with as a factor in evolution. It is certainly in some cases a conservative factor, and it is possible that it may become a cause of progressive change of type. But whether bathmic evolution has ever taken place by this means without the aid of other factors is another of the unsolved problems.

Inheritance of Acquired Characters.—An "acquired" character is one which arises during the life of the individual as the result of functional activity or in response to an external stimulus. The term is an unfortunate one, for to many minds the word "acquired" conveys simply the impression of newness without regard to the source of the change. To meet this difficulty C. L. Morgan has proposed to use the term *modification* in place of acquired character, and to reserve the term *variation* for changes of purely congenital origin. Moreover, it is often difficult to distinguish between modifications and variations. For example, deafness may be due to congenital malformation of the ear, or it may be due to disease. In the first case it would be a variation, in the second it would be a modification. Now Fay in his study of the inheritance of deafness often found it difficult to decide in which class a given case should be placed.

The factors of organic evolution that we have examined so far have been the great factor, natural selection, and a number of others more or less aiding and accessory to it. We have seen that natural selection is itself conditioned by three other factors: (1) variation, (2) inheritance, and (3) the struggle for existence.

Natural selection is only indirectly concerned with the origin of variations. So long as variations are of the right kind and are capable of being transmitted, natural selection, with the aid of isolation, will protect and develop them. It is evident, then, that if the purposeful, adaptive modifications of the individual that arise as the result of its reactions to the stimulus of its environment may become hereditary, they will be a great aid to natural selection. For they will insure the presence of the right kind of variation to be selected when it is needed. Darwin thought that such acquired characters are inherited, and he regarded them as an important aid to natural selection. The neo-Lamarckians, on the other hand, have taken the view that the inheritance of acquired characters is much more than an aid to natural selection; that it is itself a prime factor of organic evolution.

Now comes the school of Wallace and Weissmann, and says that the inheritance of acquired characters not only is not a prime factor in evolution, but it is not even an aid, as Darwin supposed, to natural selection. In fact, according to this school, acquired characters are not in any degree inherited. The question then is, Are acquired characters inherited, and if so, how far has this inheritance been a factor in the origin of species?

To discuss fully the subject of the inheritance of acquired characters as a factor of organic evolution would require much more space than we have at our command. But we may endeavor to present a few of the thoughts which seem to be of greatest importance in this connection.

In the first place, the neo-Lamarckian contention that the inheritance of acquired characters is the *prime factor* in evolution can be ruled out of court at once as manifestly untenable. There are a large number of structures in both plants and animals that can have developed only as the result of continued selection. Such are the cases of mimicry, both in form and color, warning colors, adaptations for cross fertilization in plants, and the like. But the most instructive examples, as pointed out by Brooks, are to be found in species having normally sterile individuals. In many species of polyps there are nutritive, offensive, or protective persons in each colony which never produce offspring; and among ants, bees, and termites, the most numerous and most active members of the community are sterile workers. These sterile individuals generally differ from the fertile males and females, presenting very beautiful modifications of both structures and instincts in adaptation to their very different functions and mode of life. Now as the worker has no offspring its acquired characters cannot be inherited. The evolution of the worker must be explained as the result of natural selection, preserving those queens that produced the workers best adapted to the needs of the species.

If such complex adaptations as the mechanism for cross fertilization in orchids, and modifications observed in the worker of the honey-bee have arisen through the action of natural selection without the aid of the inheritance of modifications, a strong presumption is raised in favor of the view that natural selection and not inheritance of acquired characters, has been the prime factor in evolution generally. This being granted, should we not return to the position taken by Darwin, that while natural selection is by far the most important factor in evolution, it has been aided by the favorable variations resulting from the inheritance of acquired adaptive modifications?

The amount and kind of evidence that is required to prove any generalization depend upon its theoretical probability. Now if we accept Darwin's view as to the inheritance of acquired characters, we must also accept his theory of heredity or some theory closely allied to it. The study of heredity, however, makes it clear that the only theory that corresponds with what is known of the origin of the germ cells and the subsequent development of the embryo utterly fails to explain the inheritance of acquired characters. If acquired characters are ever inherited, our theory of heredity must include some form of pangenesis and of preformation. But the only theory that agrees with the facts of development must include the contrary principles of continuity of the germ plasm and epigenesis. This makes the inheritance of acquired characters seem theoretically improbable, and necessitates a critical examination of the testimony in its favor. This evidence may be classified as follows:

1. Indirect evidence.

(*a*) Analogy between congenital and acquired characters.

(*b*) Apparent uselessness of nascent structures observed in fossils.

(*c*) Reflex actions.

(*d*) Instinct.

2. Direct evidence.

Reported cases of inherited effects of (*a*) use or disuse, of (*b*) climate, and of (*c*) food.

3. Experimental evidence.

(*a*) Brown-Séquard's experiments on guinea-pigs.

(*b*) Experiments of Hoffman, Carrière, and Buckman on plants.

It will be most convenient to take up this evidence in the reverse order. Beginning with the experimental evidence, Brown-Séquard's experiments were supposed to show that epilepsy induced in guinea-pigs by operation is inherited by their offspring. But Romanes repeated these experiments as carefully as possible, and his results were inconclusive.

Carrière and Buckman were able to produce change in plants increasing in successive generations, by growing them on different soils. But here the principle of selection was employed, and it is impossible to say how far the result is due to selection and how far to the inheritance of acquired characters. It is also to be remembered that food is one of the factors in the environment that may affect the germ plasm directly. It is possible, therefore, that the changes observed in the succeeding generations of plants may be due to the new constituents of the sap affecting the germ plasm directly. The new characters would not then be acquired characters in the technical sense, but true congenital variations. Moreover, these experiments are offset by a number of experiments made by careful observers especially to test the question of inheritance of acquired characters, which have given purely negative results. Fay found that when both parents are congenitally deaf, twenty-six per cent. of the children are deaf. When one parent is congenitally deaf and one has acquired deafness, the percentage of deaf children is 6.5 per cent., while where both parents have acquired deafness it is only 2.3 per cent., and this last percentage may be due to an error in determining whether the deafness is congenital or acquired.

So the experimental evidence, which should be expected to give the most conclusive answer, is after all unsatisfactory.

The direct evidence as a whole is worthless. Most of the cases have been reported by unscientific persons unskilled in exact observation. The cases in which there have been competent observers can be explained as well either as the result of selection of congenital variations or as the result of the direct effect of environment upon the germ plasm.

It is the indirect evidence that offers by far the best cases in favor of the inheritance of acquired characters. In the first place, that the effects of use and disuse of parts and the effects of external conditions, climate, food, etc., are inherited, is a matter of common belief. We know the effects of these causes upon the individual, and we know that very minute individual peculiarities frequently are inherited. It is reasonable to suppose then that peculiarities caused by external conditions are inherited with the rest. No one can claim, however, that this line of evidence offers more than a presumption in favor of the inheritance of acquired characters. A better line of indirect evidence is furnished by those adaptations which apparently could not have been of use in the early stages of their evolution, and many palæontologists believe that they find in extinct species such nascent structures and that these prove the inheritance of acquired characters to be the prime factor in evolution. This is regarded as especially true of those cases in which a high degree of co-adaptation is required. Spencer, for example, presents the case of the giraffe as a form undoubtedly due to the inherited effects of functional activity. For as he rightly says, in order that the giraffe may carry his long neck, the forelegs must be lengthened, and the hind legs shortened. In fact, the whole shape of the body has to be altered, involving changes in a great many tissues and organs. If a breeder is trying to produce a variety having a new combination of characters, he selects individuals, some having one character, some another, and still others a third, and so on; and by causing these to breed together finally obtains individuals in which these characters are all combined. The Boston terrier and the Plymouth Rock fowl are excellent examples of such a blending of characters by artificial selection.

Now Spencer argues that it is impossible for co-adaptation to be produced by an analogous process in nature, for it is inconceivable in the case of the giraffe, for example, that any one of its peculiarities occurring alone in an individual could be of sufficient value to lead to the preservation of the animal by natural selection. In fact, some peculiarities without the others, for instance, the long heavy neck without unusually strong shoulders to support it, might be so great a disadvantage as to lead to speedy elimination. In order that the giraffe should be produced by natural selection, according to Spencer, it would be necessary for all of the co-ordinated adaptations to appear at the same time and in a large number of individuals. For, in the first place, these variations could be of no value unless all were present and co-ordinated; and in the second place, unless they occurred at the same time in a large number of individuals, they would be lost by the swamping effect of intercrossing. Moreover, they must continue to vary in the right direction in a large number of individuals. All of this Spencer holds to be impossible without the aid of the inheritance of acquired characters.

A new variety may be supposed to arise in one of two ways, either (1) from the blending of a series of adaptations each in itself of selective value, or (2) by the co-adaptation of a number of variations each so slight as not alone to have selective value, but when combined with the others producing a form sufficiently superior to its fellows to be preserved in the struggle for existence. Even Spencer would admit that the first method is easily explained by natural selection, if the swamping effect of intercrossing can be eliminated by some mode of isolation. But, if new forms are produced in the other way, by co-adaptation of variations in themselves not of selective value, as Spencer supposes in the case of the giraffe, natural selection is not so easy an answer.

These phenomena of co-adaptation present one of the best lines of evidence that has ever been brought forward in support of the theory of the inheritance of the effects of use, and yet it does not seem to be at all conclusive. To begin with the case of the giraffe, it would seem that the development of this species from an antelope-like ancestral form may be explained by the mingling of adaptations as well as by the sudden appearance of true co-adaptations. Those who take the opposite view, while insisting upon the adaptive value of functional modifications, that is, characters acquired as the result of the use of parts, seem to forget, as has been pointed out by C. L. Morgan and others, that purely fortuitous, or accidental, congenital variations in the same direction may occur at the same time. The element of environment that has led to the evolution of the giraffe was evidently the need of reaching high foliage. Now in order that the animal shall reach this foliage the head must be raised high from the ground, and this may be accomplished by lengthening the neck or by lengthening the fore-limbs, or by lengthening both at the same time. At the beginning, therefore, of giraffe evolution, those animals which varied toward greater length of neck and those which varied toward greater length of fore-limb or greater height of shoulder would have an equal chance of surviving in the struggle for existence, provided the muscles necessary for carrying this increased weight were equally *capable of being strengthened by exercise.* These individuals would breed freely together, and finally offspring would be produced having both neck and fore-limbs longer than in the ancestral form. Again, the effects of exercise would compensate for the increased weight, and, again, the individuals best developed would survive. Now we know practically that every part must have varied on both sides of the average character of the race. A large number of individuals inheriting the above characters must have presented congenital variations of the co-operating parts of the body of the same character as those modifications produced in the others by functional activity. Such congenital characters might occur separated, some in one individual, some in another; but wherever they occur the animal will have a distinct advantage, for so much will be, so to speak, ready-made, and just so much less to be developed by exercise. You can make an athlete of a man with a congenitally strong back and weak legs more quickly than you can make one of a man whose back and legs are both congenitally weak. In time, by careful training, the two men might become equally strong, but in natural selection time counts. The sooner an animal can hold its own with its fellows, the better its chance for surviving to produce offspring.

It seems to us then, that if we remember that *fortuitous, congenital variations and modifications due to functional activity may be of the same character and may occur side by side,* there is no longer any difficulty in the theory that even so complicated a co-adaptation as is presented by the giraffe may arise by blending of minor congenital adaptations and therefore may be explained by natural selection. Moreover, it is to be borne in mind that it is a fallacy to speak of any one character as being selected. It is not a single character that is even preserved by natural selection, but it is the individual as a whole that is selected. While a favorable character may not of itself be of selective value, it may be perpetuated because it occurs combined with other favorable characters *either congenital or acquired,* all so blended as to give their possessor superior advantages. Individually acquired modifications may, therefore, become important factors in evolution, not because they are inherited, but because by their acquirement the individual is able to supplement the deficiencies in its congenital characters. And when thus supplemented by individually acquired adaptive modifications, the inheritable congenital characters may be preserved by natural selection and continued from generation to generation, until by the operation of fortuitous variation and natural selection the acquired modifications are replaced by congenital characters of the same kind. So we may have two forms of co-adaptation: first, co-adaptation of mingled congenital and acquired characters, which precedes and prepares the way for the second, co-adaptation of purely congenital characters.

The question whether co-adaptation by the blending of favorable congenital variations really occurs in nature is answered best, according to Romanes, by a study of reflex actions and of instincts. Turning now to the evidence from reflex actions, it seems to us that Romanes has been unfortunate in selecting this line of evidence upon which to pin his faith in the *occasional* inheritance of acquired characters. He asks what use an animal can have for lower reflex centres when the higher brain centres are capable of originating the same nervous impulses. Now no one who has ever learned to dance, to swim, or to ride a bicycle will fail to appreciate the superiority of reflex over conscious action. No one can become an expert swimmer or rider until the movement is of the nature of a reflex, although the higher centres, the rational processes, may still be indispensable in case of accident. Romanes argues at length in regard to the apparent uselessness of many reflexes, together with the completeness of the mechanism required, and the consequent difficulty of explaining them by natural selection, and then proceeds to show that "if function produces structure in the race as it does in the individual," all is easily explained.

Now, in the first place, does function produce structure in the individual? Function may be said to produce size, strength, hardness, flexibility, and the like, but no case is on record where new muscles, new nerves, or any other new structure has been produced by any amount of functioning. Moreover, how can a structure be the result of a function when the function arises from the activities of the structure in question? A given intelligent act cannot take place until the whole neuro-muscular mechanism concerned in that act is complete, any more than if it were a reflex; and it is not evident how one can be explained by gradual development any better than the other. (It is like saying that a man can make a bicycle by riding it.) But even if we allow that a reflex mechanism may be the inherited result of intelligent action, this action must have been of a great deal of use to have been repeated often enough to make so great an impression on the organism. And if it has been of so great use it may well have had a selective value, and its development may then be explained by variation and natural selection.

It would seem, therefore, that reflex mechanisms and actions may be explained best by the principles of change of function and natural selection. When you learn to ride a bicycle, or better, when you learn to swim, you develop a new set of reflexes, but no new sense organs, nerves, or muscles, only the old ones in new combinations. Now the study of the morphology of the nervous system in any great group of the animal kingdom shows that a change of function in different parts of the nervous system is just what has taken place as we go higher in the scale of organization; and it is easy to see how any variation toward more intimate union of parts habitually used together would be preserved by natural selection until their interaction would be so easy as to become reflex.

Turning to instinct—if we regard it as "hereditary habit," that is, if we suppose it to contain an element of transmitted experience, all is easily explained. The simple instincts are easily explained by natural selection, "but in all cases where instincts become complex and refined, we seem almost compelled," according to Romanes, "to accept Darwin's view that their origin is to be sought in consciously intelligent adjustments on the part of ancestors." He cites the case of a species of wasp of the genus *Sphex,* which paralyzes caterpillars by stinging them in each of the nine minute nerve centres before depositing them in the cells for the larva to feed upon. He regards it as impossible that such an instinct could have arisen by natural selection unaided by originally intelligent action. In regard to this it may be said that, if the complicated maternal instinct of the *Sphex* wasp is an "inherited habit," its ancestors must not only have possessed great industry, but also a very remarkable knowledge of anatomy. Moreover, it has been shown very recently (1898) by Mr. and Mrs. Peckam ("Instincts and Habits of the Solitary Wasps") that the instinct of *Sphex* is not so exact as was formerly supposed. Not only is there a great deal of individual variation in the instinct of this species, but there is a gradation from this through other genera to those having much simpler instincts. They have shown that instinct may be acted upon by natural selection, just as may any other function or structure.

In conclusion it may be said, therefore, that in the writer's opinion, while acquired characters are of great importance to the individual, and their periodic recurrence in successive generations may be necessary in the formation of co-adaptations as an aid to natural selection, the *inheritance* of acquired characters is not only not the prime factor in evolution, but that it is not a factor in any degree.

Differential fertility appears to be an important factor, being, according to the circumstances, either an aid or a hindrance to evolution; preferential mating is the best explanation of the origin of certain secondary sexual characters; and some form of isolation must be present, or else divergent evolution is impossible, and without isolation it would be impossible to explain the differentiation of species by characters of less than selective value; but the chief cause of organic evolution is natural selection, or the survival of the fittest in the struggle for existence. *Robert Payne Bigelow.*

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EVOLUTION OF MAN.—The science of anthropology has advanced with surprising rapidity since the discovery of the two principles, evolution and psychic unity, the latter contributing evidence in support of the theory of evolution similar to that furnished by the homologies of biology. From each of the recognized divisions of anthropology evidence has been accumulated to establish the unity of the human species and to warrant the assumption that it has developed from the original mammal through the lemuroid and anthropoid stages. A few zoologists would derive man directly from the lemurs, but while it is recognized that man has many characters in common with the half-apes and even with lower forms, anthropologists are unanimous in deriving him from a generalized anthropoid precursor. The phylogeny of the mammalian group is given in the preceding article upon *Evolution*, so that we may devote our attention here to the problems involved in the determination of man's immediate ancestry. We shall seek such evidence as may be found within the human group, neglecting argument by analogy, which can never be wholly convincing.

I. SOMATOLOGY.—The modern science of physical anthropology interprets the data supplied by embryology, ethnic and comparative anatomy, and statistical anthropometry by the aid of the theory of evolution which alone renders them comprehensible.

1. *Embryology.*—In addition to the indications of relationship to lower animal forms there are many marks of phylogenetic proximity to the anthropoids in the human fœtus. By the dictum of "the first biogenetic law" we interpret the greater resemblance of the young of anthropoids and man to mean that both sprang from a common ancestral type. Not to deal too exclusively with general statements let us review a few of the more salient facts.

The lanugo of the fœtus recalls the hairiness of primitive man and his immediate ancestor, a condition seen even now in an occasional unfortunate adult. The free projecting tail of the embryo certainly pertains to an earlier form than the anthropoid but not necessarily earlier than the lower primates. Again it is to be noted that this character sometimes persists in human beings until maturity, either with or without free vertebræ. Until the very end of the nineteenth century rumors of the discovery of tribes of tailed men were circulated from time to time. It has been suggested that such fables may have arisen from the practice of wearing a sort of caudal appendage, as among the Sioux Indians and the Nagas of Manipur. The theory of an ontogenetic shifting of the pelvic girdle is generally accepted, reducing the number of presacral vertebræ from the number existing in most of the anthropoid families and from the ancestral condition. The presence of cervical and lumbar ribs in the embryo recalls the type prevailing among the anthropoids where the orang alone has as few as twelve pairs. The shape of the entire thorax in the embryo is of the primary type seen in the lower apes. One of the most noticeable simian characters to be seen in the embryo is the proportionately long fore-arm which in the embryo of two and a half months equals 88.88 per cent. of the length of the humerus as compared to 72 to 73 per cent. in the adult European, 78 or 79 in the adult negro, and 90 to 94 in the chimpanzee. The os centrale of the human embryo is found in but one group of anthropoids among adults, though it occurs in most monkeys. The short lower limbs of the fœtus suggest the adult anthropoid condition. The fibular malleolus, much less important than the tibial in apes, is less developed in the fœtus and among Australians and other low races. The opposable condition of the great toe in fœtal, and even infantile life is an often cited example of the retention of an ape-like character.

Among the muscles we may refer to the condition of the pyramidalis which in the child resembles that of the apes and lower mammals; also to the interossei pedis muscles which in the human embryo are distributed as in some of the lower apes and in lesser degree the chimpanzee and orang. The vermiform appendix is proportionally larger in the fœtus.

In the brain, the most distinctively human of all the organs of the body, the ontogenetic changes in the character of the surface and the disposition of the vesicles repeat phylogenetic development in a marked degree. Resemblance between the young of the two groups is nowhere more striking than in this organ. Hints of the anthropoid condition are not numerous in the sense organs of the embryo, but in the external ear such conditions are fairly prominent; the tip shifts downward and not until the eighth month does the human ear fold begin to roll inward. The palatal ridges of the embryo (six or seven) suggest the anthropoid condition, though they are rather more numerous in the apes. The milk teeth of man and anthropoids are closely similar and the dental formulæ are identical in the two groups.

These are a few of the more important characters that point to an anthropoid ancestry. They are but a fraction of the number of characters that occur in the human embryo which are indicative of lower stages of development, but taken altogether they lend strong support to the evolutionary hypothesis.

2. *Ethnic and Comparative Anatomy.*—Together with physiology and anthropometry it comprises the greater part of the science of somatology as now taught in our universities, and the evidence of the relationship of man to the anthropoids is rapidly accumulating, both from the work done in our laboratories and from that accomplished among what we are pleased to term the lower races, though it must be understood that in many respects these races as well as some of the lower animals exhibit characters of decided superiority. We may summarize the facts as follows: Man resembles the anthropoids more closely than do the latter the American monkeys. In other words, the gap between the human and the nearest non-human group is far less striking than that between many mammalian groups. Among skeletal characters we find that the spinous processes of the cervical vertebræ are simple and undivided among low races. The clavicle and the scapula are proportionately longer and hence more simian in the negro than in the Caucasian. The arm of the negro exhibits two opposing characters: it is higher in its shorter humerus and lower in the longer radius than the white; the proportion of the radius is more exaggerated in the Veddahs of Ceylon. With a slightly shorter femur and a tibia of equal length the negro possesses lower limbs of a more simian type than the white. In the torsion of the humerus the black races stand midway between the anthropoids (130°) and Europeans (164°). The condition known as perforate humerus or the occurrence of the supratrochlear foramen, which is most frequent in Veddahs and Bushmen, is common in the gorilla and the orang. Among non-European races it is not the blacks alone that retain the ape-like prehensile foot beyond the period of infancy; many Eastern peoples possess this character, notably the Japanese. However, it is a pincer foot, not a hand foot.

The skull continues to be the most significant portion of the skeleton for classificatory purposes notwithstanding some contradictions presented by single characters. The projecting brows of the gorilla are seen in certain prehistoric crania to be described later and in the Melanesians as well as in rare instances among Caucasians. Many human groups possess the flat nose of the anthropoids. The fusion of the nasal bones that is normal in apes occurs more frequently in lower races than in higher. Australians, Hawaiians, and others have no sharp line of demarcation between the nasal opening and the maxilla beneath it. The temporal crest assumes a simian appearance among the Oceanic blacks. The meeting of the temporal with the frontal in the form known as pterion in K is most frequent in the Veddahs, Australians, and negroes; in anthropoids it is seen in the gorilla. Considerable variation in the foramina of the skull occur: the parietal are more frequently wanting in the higher races, the middle lacerated is larger in Europeans than in lower races and is wanting in anthropoids. The palatine suture of certain low races by its curved and irregular course resembles that of the apes. The form of the palate among low races often resembles the U-shaped alveolar arch of the anthropoids and occurs occasionally among Caucasians as an individual variation. The teeth of the Australians increase in size backward as in the apes. The New Caledonians not rarely develop a third pre-molar, the normal condition in New World monkeys. The shortened inferior maxillary of the European is causing a reduction in the number of teeth so that the upper outer incisors are sometimes wanting and the wisdom teeth as well. This change is also taking place among Amerinds. We have observed cases of suppressed third molars among the Esquimaux and all stages between rudimentary third molars and those larger than the first and second molars among other Amerinds. The hyoid of negroes resembles that of apes more closely than does that of Caucasians. The prognathism of the ape is conspicuous in the extinct Kalangs of Java, the Akkas and other Africans.

The only well-marked gap existing between the crania of man and anthropoids is in capacity. The highest recorded capacity for the latter is about 590 c.c. while the lowest for the former is that of a normal Veddan skull of 950 c.c. While the methods of determining cranial capacity are unsatisfactory, and the results of different observers are scarcely comparable one with another, yet approximately correct averages have been recorded for most human groups which show that the lowest capacity exists among the dwarf races of Africa, the Veddahs of Ceylon and their neighbors, the Andamanese. The question of capacity is the most interesting one concerning fossil human crania.

3. *Variation.*—Notwithstanding the potent influence of mixture of races, the constant mingling of blood owing to conquest, slavery, or friendly alliance, all tending toward uniformity of type, the human body is in the highest degree variable. The tendency toward uniformity has produced a well-defined species with varietal differences within the group; but each organ of the body and the proportions of the whole vary to such a degree that the examination of a large series of anthropometric data cannot but cause the investigator to marvel at the continuance of the human type. We now know that the black, white, yellow, and red varieties of the race perfectly intergrade; hence we need not expect by such comparisons as have been made in the preceding paragraphs to discover differences in the various human groups that shall equal those existing between this species and the anthropoids belonging to four separate families.

Even in the size of brain case, the range of normal variation in man is from 900 to 1,800 c.c. while the range from microcephalic idiots to pathologic megacephalic skulls is from 350 to 3,500 c.c. The range of variations in cranial capacity in a small series of 42 Auvergnat skulls was 676 c.c. The range from the earliest times to the present is inconsiderable and inconclusive. The proportions of the brain case are fairly constant within the tribe but not in the larger divisions of the species: we have long-and-round-headed Caucasians, Mongolians, negroes, and Amerinds, with all possible intermediate forms. In the torsion of the humerus, often cited as a good zoological character separating man from the other animals, the variation is from 164° in Europeans to 134° in Australians, the minimum being at least seven degrees below the average for the gorilla, less than the gap separating the lowest anthropoid from the lower apes and monkeys which, in their turn, are lower than the marsupials and others. Independently of the normal variation in the length of the humerus, the difference between the right and left sides sometimes amounts to 2 cm. The other long bones exhibit a corresponding variability; indeed, the tibia has been termed the most variable long bone in the limbs of man. The thickness of its shaft varies from forty to one hundred per cent. of the antero-posterior diameter and the outline varies from almost a circle through oval, triangular, and quadrangular forms. Physiological causes are supposed to bring about the platycnemic or flattened condition and the retroversion of the head as well as various degrees of curvature of the shaft. Examples of similar variations might be multiplied indefinitely from an examination of other parts of the skeleton and of the other tissues, particularly the muscles, where variation becomes excessive, and we yet continue in our laboratories to record cases of "new muscles."

II. ETHNOLOGY.—The study of the culture of living races furnishes little evidence in favor of our thesis; although it is true that in the Amerindian division the Fuegians, the Seri of the Gulf of California, and perhaps the Botocudo stand out little above the apes. Subsisting mainly upon raw food and manufacturing implements and weapons of the simplest sort they are not industrially much superior to the anthropoid that has learned to preserve the conveniently shaped stone for breaking cocoanut shells. Among the blacks, the Andamanese, the Veddahs, some Australians, and perhaps a few other groups are equally savage in culture.

From the discoveries of recent years it is now known that the earliest migrations peopled the earth before or shortly after the transition to the human stage of development, so that the several native cultures have been moulded by environment and acculturation rather than by common descent. Naturally, similar environments, similar conditions, result in like products which are termed ethnic parallels, and the phenomenon is known as psychic unity. The extreme position which maintains that "thinking merely goes on within us" governed by unalterable laws that direct every race through the same phases in its upward struggles has been abandoned by most anthropologists, but the controversy has stimulated research and indicated the true factors governing primitive cultural development. By the study of present-day savages we learn of those of prehistoric times. But again we are not forced to rely solely upon analogy. Let us see what positive evidence is available.

III. Prehistoric Archæology.—From the Glacial gravels of Europe, Asia, and Africa have been taken flaked stone implements of a rude and simple sort that mark the beginning of the industrial art in stone. Apparently without domestic animals, possessing a knowledge of the use of fire, our Pleistocene ancestors appeared in Europe at least as early as the Interglacial epoch and possibly before. Cultural remains are fairly abundant from which we may reconstruct the history of this far-off people, but of skeletal remains but few have been discovered. Many mistakes have been made in the identification of more modern skeletons as of Pleistocene provenance; however, at least two skulls and two other inferior maxillaries are referred to the Chellian or earliest paleolithic period; about a dozen in all may be assigned to the Quaternary epoch; and these are in but a fragmentary condition. Obviously the attempt to reconstruct the physical type of the earliest known inhabitants of Europe from such scanty material is extremely hazardous. Naturally enough the most minute and exhaustive study is made of these specimens, the observer usually bent upon discovering pithecoid or anthropoid characters.

The human remains that may be accepted without controversy are the skulls from Olmo, near Chiana in Tuscany, and from Egisheim in Alsace. The maxillaries are those from the cave of La Naulette, near Furfooz in Belgium, and the fragment from the Schipka cave in Moravia. The skulls are dolichocephalic but not at all ape-like. The jaws present certain low characters that are not uncommon among whites at the present day. One of the most widely known skulls is that of Neanderthal, Rhenish Prussia, which cannot be proven to be a genuine Quaternary relic, and even if it be such no great weight can be attached to its somewhat simian brows and low frontal because we find its modern counterpart in men of no inferior intelligence, as, for example, Robert Bruce. Possibly such individuals are to be accepted as examples of reversion, though here again we must remember that normal variation about a mean will produce a low frontal in the millionth skull. It is noteworthy that the oldest skulls of Europe present fairly uniform proportions of breadth to length, and are dolichocephalic. In America both long and round skulls are found in Quaternary strata, showing that at that distant day differentiation had proceeded far enough to establish two distinct types. At Santos, on the south coast of Brazil, was found a skull that resembles the Pithecanthropus erectus of Java. It is somewhat less dolichocephalic but has the same marked constriction behind the orbital region, a characteristic of the gibbon skull. Other South American skulls show this same trait, and from their study the conclusion has been reached that man is more closely related to the gibbon than to any other anthropoid. This conclusion is independently reached from the study of the skull or brain cap together with two molars and a femur from Trinil in northeastern Java. These remains indicate that the animal to which they belonged was dolichocephalic, had a cranial capacity of about 1,000 c.c. (average for Europeans 1,565 c.c.), was tall, and walked erect. This creature was named Pithecanthropus erectus by its discoverer, who believes that it represents a true transition form from the anthropoids to man and that continuity in the upward scale of development has been established at last. The skull differs from the ape's cranium in having a higher vault, in being devoid of strong crests and ridges, and in having an occiput arched like that of man though somewhat suggestive of that of Hylobates. Pithecanthropus is regarded as having descended from Anthropopithecus sivalensis of the Indian Miocene which with Hylobates stands nearest to man of all the anthropoids. Pithecanthropus comes from the Upper Pliocene or Lower Pleistocene, hence in sequence of time stands between anthropopithecus and man. The discussion concerning the significance of this fossil is not yet closed notwithstanding the fact that various authorities announce from time to time that it is; however, the preponderance of opinion is in favor of the acceptance of the original theory that pithecanthropus is a true transition form.

Both in the New World and in the Old the discussion yet continues concerning the length of the last Glacial and the Post-Glacial period. The estimates vary, according to the method or the prejudice of the investigator, from a few centuries to hundreds of thousands of years. Could we definitely establish the existence of Tertiary man the period of human occupation would be immensely increased. We may postulate a Tertiary "precursor," a "proanthropos," but exhibit one of his bones in the broad light of day we cannot. Human bones have been occasionally found buried in Tertiary strata, but they have been shown to be much later than the strata in which they had been interred. Artifacts purporting to be of the Tertiary epoch are announced from time to time, but there is always some flaw in the evidence: they are natural flint flakes that are erroneously supposed to be artificial, worked animal bones that are found to have been gnawed by wild beasts, whale bones that have been grooved by the teeth of sharks, cracked bones that are shown to have been naturally broken, and, finally, there is often doubt as to the exact age of the strata themselves. Again, fraud is suspected, as in the case of the Calaveras skull, and the evidence must be rejected. However, no valid objection to the existence of Pliocene or even Miocene man can be maintained. The hypothesis that man could not have retained his specific characters throughout such a long period of time without doing violence to the natural laws of zoologic development seems untenable when we see how slight has been the change in other animal species, for example the lion, that was the contemporary of the European cave-dwellers of early Quaternary times, as compared with the modern species.

Whether man lived in Europe before the Interglacial period is, then, an unsolved problem, but if true that he first appeared on that continent after the first Glacier, we know next to nothing of the length of time that he had lived in more tropical regions. The now sterile Sahara was once a well-watered region, as is shown by the terraced valleys worn by flowing streams and by the crocodiles that yet survive from the aquatic period in the Ahaggar Mountains. There, too, we find pictographs portraying animals that no longer live in the region. It is nearer the centre that archæologists now regard as the place of origin of the entire race. That there was but one place of origin is no longer disputed by any competent anthropologist, and this centre is located in either the northern or northeastern part of Africa or in the so-called Lemuria, the region now occupied by the Indian Ocean. The geologic evidence of the existence of this continental area is indisputable; that it was occupied by primitive man seems probable from the fact that the climatic conditions were most favorable for the welfare of a naked frugiverous animal; it is within the limits of this area that the most primitive fossil form has been found; it is on the borders of this area that the most ape-like human beings now live; and on the eastern and western limits of this zone that anthropoids yet flourish; it is on the northen borders of this area that the earliest civilizations have arisen. The dispersion from this centre must have taken place not later than the Old Stone Age, and the primary divisions of mankind were already specialized in their several geographic areas before the development of any distinctive culture. Paleolithic implements are regarded as very much the same in character in the Eastern and Western hemispheres, but all Neolithic and subsequent artifacts differ according to the locality whence they come.

Since the first peopling of the earth there seems to have been little migration in the New World, Australia, or to any significant extent in Central Africa. These countries have produced strongly marked varieties. The evidence is rapidly accumulating to show that the Caucasic division arose in Africa in the region of the Sahara and northward, and not in Asia. Two or three land bridges then spanned the Mediterranean, and there was land connection to the British Isles, so that no obstacle prevented the invasion of Europe or the migration to and fro of the tropic and temperate fauna of the two continents. The movements of the European and Asiatic races have been chiefly within limits of similar environmental conditions, so that the extensive migrations, as contrasted with the limited ones of the black and red races, have not apparently interfered with the specialization of racial types. Indeed, we are discovering that the principal types of Caucasians were already specialized in Africa before the migrations to Europe began.

We may summarize the facts so far as known concerning the time and place of man's origin and the characteristics of his early culture as follows: Before the period of proto-historic Egyptian, Mediterranean, and Eastern civilizations there was an epoch during which implements and weapons were made of stone and were smoothed and polished. At a yet earlier period chipped or flaked flints and other stones were used. The rudest types of these come from strata that are referred to the Interglacial period of Europe. In those strata human artifacts cease; there also occur the earliest traces of human skeletal remains. These remains are few and fragmentary, but they indicate that the race of that remote epoch differed but little in physical characters from that of today. The order of succession of these geologic and culture periods is known, their duration is not. The place of origin is provisionally located in the tropical region north of the Soudan in Africa or in the sunken Lemuria. Paleontology furnishes but one bit of evidence of any value, the remains from Java. No other skeletal remains have been found anywhere that can be regarded as belonging to any generalized precursor of the human race. In fact only a few fragments of fossil ape bones have been discovered. Embryology and ethnic and comparative anatomy combine to prove the theory of development from a generalized primate the remains of which may be found to-morrow or which may never be found. The Pliocene fossil-bearing beds of the lands bordering upon the Indian Ocean offer the most promising fields for research to-day. The problem is now one for paleontology and geology to settle, biology can do little more. *Frank Russell.*

EXALGINE.—Exalgine is the trade name of methylacetanilid. Its chemical formula is $C_6H_5NCH_3C_2H_3O$; it is formed by the addition of the methyl group, CH_3, to acetanilid, $C_6H_5NHC_2H_3O$, replacing one atom of hydrogen.

It occurs as beautiful needle-shaped crystals, colorless, and with a faintly aromatic odor and slightly pungent taste. It is almost insoluble in cold water, slightly soluble in hot, and very soluble in dilute alcohol. From sixteen to twenty grains may be dissolved in half a drachm of rectified spirit, and this solution may be diluted with two or three ounces of water without producing any precipitation. Its melting point is 100° C., and it may be heated to its boiling point, 240° or 250° C., without causing decomposition. By the addition of soda it is decomposed and partially converted into methylaniline. Hydrochloric acid causes the same decomposition. Exalgine may be distinguished from acetanilid, phenacetin, and methacetin by treating two grains of the suspected salt with twenty minims of hydrochloric acid. Phenacetin remains undissolved; acetanilid dissolves but separates again in crystals; methacetin also dissolves and gradually colors the solution reddish-brown on the addition of one drop of nitric acid. Another test for the presence of phenacetin or acetanilid is to treat a chloroform solution with ten volumes of petroleum ether; if either of these substances is present a turbid mixture is formed. The presence of methylaniline and other compounds of the same base may be detected by the irritating fumes produced when the impure salt is heated with alcoholic solution of potash and chloroform. Its purity may be further tested by dissolving in nitric acid, which forms a colorless solution; when heated this becomes of a bright yellow color, and evolves irritating fumes.

Methylacetanilid was discovered in 1874 by A. W. von Hofman. Its therapeutic properties were studied to a certain extent by Kahn and Hepp during their researches upon acetanilid and other antipyretics, but it was not until March, 1889, that Dujardin-Beaumetz and Bardet made known its value as an analgesic, in a communication to the French Academy. A very careful series of experiments, both physiological and clinical, enabled them to indicate its therapeutic qualities with a marked degree of accuracy. In common with the other members of the aromatic series it was found to possess antiseptic, antipyretic, and analgesic properties, and they also pointed out that its action on the nervous system should make it of value in the treatment of many functional diseases. It was as an analgesic that they particularly advocated its use; the addition of the methyl atom to acetanilid had intensified this action without affecting its antipyretic properties, but it was found that a dose large enough to produce antipyresis was accompanied by such alarming toxic symptoms that this use could not be considered. They advocated its employment in headache, migraine, neuralgia, neuroses of the viscera, the pains of locomotor ataxia, and in all non-febrile affections accompanied by pain. The dose they advised was from gr. iv. to gr. vi. (0.25 to 0.40 gm.) in a single dose, or from gr. vi. to gr. xiss. (0.40 to 0.75 gm.) in the twenty-four hours.

In Great Britain the notice of the profession was particularly directed to the value of this remedy by Professor Fraser, of Edinburgh,[1] who gave the results of his experience with it in the Royal Infirmary. The remarkable point in Professor Fraser's paper was the smallness of the dose and the success that followed its use in such quantities. The usual dose was half a grain in spirituous solution, repeated three or four times a day, according to the return of the pain. In some cases it was increased to one or even to two grains, and in a few instances four grains were given; the largest quantity given was fourteen grains during the twenty-four hours. In the cases of neuralgia and angina half-grain doses relieved the pain in ten or fifteen minutes, and in one hour there was perfect ease, which lasted for from three to nine or ten hours, and in many instances a complete cure was obtained. In sciatica and locomotor ataxia one and two grains secured the same freedom from suffering. In cancerous disease and in the pain accompanying an aneurism the success was less marked, and it was in these cases that the larger doses were given. Dr. Fraser considers that the smaller dose is the proper method of administering the drug, and that all its virtues may thus be as readily secured as with the larger doses.

Following Dr. Fraser's paper came a number of reports of successful results with half- and one-grain doses, by Drs. Herschell,[2] Farrar,[2] Holden,[3] Maloney,[4] and many others. Further experience has proved exalgine to be an analgesic and antispasmodic of much value, which, although not in very general use, is constantly employed. It is of service in all pains of a purely neurotic origin, and by many it is thought to be particularly valuable during the course of a febrile attack. It has proved of less value in painful conditions due to organic disease or mechanical causes. In England the small dose advocated by Fraser appears to predominate, but in other European countries and in America the larger dose of four grains is generally given.

Exalgine has been used with favorable results in infantile troubles. Dr. Moncorvo[5] publishes his experience of its use in twenty-one cases of children ranging from one to twelve years of age, in which it was given for the relief of pain. He considers it a very useful agent. It was well borne in every case, no unfavorable symptoms being ever noticed. The dose commenced with was three-fourths of a grain, increased in some cases to five grains. In one case choreic symptoms were present and were improved.

Its use in chorea has been reported upon by Dr. Hugo Löwenthal.[6] Thirty-five cases were treated with doses of three grains, given usually three times a day and never exceeding fifteen grains in the twenty-four hours. The effects were very satisfactory. The mild cases were cured quickly, but the more severe ones were less influenced and required more time. The beneficial effects of the treatment were most marked in the cases in which it was given early in the course of the disease, in two cases a cure being effected in eight days. A favorable influence over the mental state was also noticed; the fear and nervousness were lessened and the intelligence brightened. In some of the cases in which it was administered for a prolonged period, nausea, vertigo, headache, and other distressing symptoms were noticed.

Unfortunately the occurrence of toxic symptoms is not infrequent. No fatal termination has yet been reported, but the condition of the patient sometimes becomes very alarming both to the friends and to the physician. The toxic disturbances, however, occur long before the fatal dose is reached. Experiments on animals have shown that the lethal quantity is seven and a half grains for each two pounds of the weight of the animal, and three grains, it has been found, will give rise to severe symptoms. The poisoning arises from the action of the drug on the nervous centres as well as from the alteration that occurs in the condition of the blood. The changes in the blood are the same as those which are produced by all aniline compounds; that is, the hæmoglobin is altered into methæmoglobin and the function of oxidation is interfered with. The patient is made aware of the approach of the toxic action by a sense of fulness in the head, a constriction and oppression of the chest, dyspnœa, vertigo, dizziness, numbness, and disturbances of vision. This is followed by a rapid pulse, shallow respiration, and all the sensations of death with symptoms of asphyxia and collapse. Unconsciousness is common in the severe cases of poisoning; convulsions do not so frequently occur.

Generally, very large quantities are given before any ill effects are noticed. It is very rarely that any disturbance of the skin takes place, but cases have been reported in which an erythematous rash has appeared on the skin, and in some instances the buccal mucous membrane is also affected.[7] In one instance[8] the drug was continued for seventeen days, in gradually increasing doses, and during the last seven days eighteen grains were administered daily. In another case[9] thirty-six grains were given within nine hours, and in still another[10] twenty-four grains within two hours. The ill effects of the drug generally follow its prolonged use or the administration of large doses, but in some instances quite small doses have produced very alarming effects. An instance[11] is reported in which two doses of three grains each caused all the serious symptoms of poisoning, and another instance is known in which two doses of five grains each were given with the same effect. A remarkable case[12] is reported in which, in an adult, two doses of one and two grains, respectively, produced most profound prostration. The symptoms came on about an hour after the administration of the last dose, while the patient was sitting at a table engaged in a game of cards. He first complained of a fulness in the head and suddenly fell prostrate, unable to speak or move, and gasping for breath. A second attack took place in about an hour, and the oppression and dyspnœa continued for several hours. In another instance a dose of eight grains produced alarming symptoms.[13]

Very different from these cases are those in which very large quantities have been given without evil consequences. Dr. Churton[14] reports two such cases. In the refilling of a bottle of medicine a mistake was made by which a solution was prepared of one grain to a drachm, instead of one grain to the ounce. The medicine was given as usual, four grains instead of half a grain being contained in each dose. This was continued for several days, and during the last twenty-four hours before the mistake was detected the patient was given forty grains. The pulse and respiration were rapid, and the patient complained of a burning sensation in the stomach, but no other effects were noticed. The second patient was given twenty-four grains from the same preparation, but it failed to produce any other effect than slight vertigo and a sense of being "dazed," which caused her to walk unsteadily. The quality of the drug is vouched for, as it was given to a number of patients with satisfactory results, and small doses were again given to the first patient, and its analgesic action was secured.

The quality of the drug undoubtedly affects its action, and in many instances explains the varying results that follow its use; but certain conditions of the system must exercise a decided influence, probably by promoting the decomposition of the drug and the formation of more toxic compounds. Mr. Bokenham[8] dwells upon this point in his remarks upon two cases of poisoning and suggests that some condition of the blood preceding menstruation may assist this reaction. The activity of the action is also influenced by the time of its ingestion. Professor Fraser and others, who find benefit in the small doses, always recommend that it should be given on an empty stomach, while those who use the larger doses advise it to be given after meals, and others still have remarked that the toxic symptoms arise when it has been given before meals. In the majority of cases the toxic symptoms pass away without requiring any assistance, but when the depression and dyspnœa are severe, stimulating remedies must be used. Alcohol has been resorted to, in most of the cases of poisoning, with apparent benefit, and hypodermic injections of ether have also been employed. In the cases reported by Dr. Jones[8] marked relief was secured by the use of strychnine in addition to the stimulants. Two minims of the liquor strychninæ were given hypodermically and ten minims of tincture of digitalis by the mouth. In these cases the inhalation of nitrite of amyl and the administration of nitroglycerin by the mouth, in doses of gr. $\frac{1}{100}$, increased the cyanosis, showing that the arterial as well as the venous blood was altered.

Upon the lower animals the hypodermic injection of exalgine produces violent epileptiform convulsions, salivation, fall of temperature, dyspnœa. The blood becomes dark in color and contains an abundance of methæmoglobin.

The following conclusions have been arrived at by Marandon de Montyel[15] from clinical observations on patients in whom the use of the drug had been pushed to its physiological limits: It has no influence on digestion. If the stomach is empty it causes an increased flow of saliva, a bitter taste, and a sense of tightness about the epigastrium. The pulse, respiration, and temperature are lessened in patients without convulsive tendencies. Vertigo, flashes of light, and ringing in the ears are frequent. A local or general cyanotic surface, sensations of cold, numbness, and formication, are prominent symptoms. The action of the drug is prompt and the effects are recovered from promptly, the brain being the first organ affected and the first to recover. When it is administered after meals its physiological action is less marked.

Beaumont Small.

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[1] British Medical Journal, February 17th, 1890.
[2] *Ibid.*, July 19th, 1890.
[3] *Ibid.*, September 27th, 1890.

[4] *Ibid.*, October 18th, 1890.
[5] Bull. Gén. de Thérap., May 30th, 1891.
[6] Berlin. klin. Wochen., March, 1892.
[7] Squibb: Ephemeris, 1899.
[8] British Medical Journal, February 8th, 1892.
[9] Medical Press and Circular, March 16th, 1892.
[10] The Therapeutic Gazette, February, 1892.
[11] British Medical Journal, July 12th, 1890.
[12] *Ibid.*, May 3d, 1890.
[13] *Ibid.*, June 11th, 1898.
[14] The London Lancet, May 28th, 1892.
[15] La Tribune médicale, June, 1892.

EXAMINER, MEDICAL.—The State of Massachusetts, in common with other States of the Union, employed the coroner's inquest as the official mode of inquiry in cases of deaths from sudden, violent, or suspicious causes, from the early history of the colony until 1877.

In consequence of corrupt practices which had become of frequent occurrence, and also in consequence of the inefficiency of the existing system, and of the inherent incongruity of an office requiring expert knowledge both of law and of medicine, a persistent movement was made by the Massachusetts Medical Society,[1] ably assisted by T. H. Tyndale, Esq., and other members of the legal profession, having as its prime object a radical change in the coroner system. This movement was heartily endorsed by the Massachusetts Legislature of 1877, and resulted in the enactment, by that body, of the following statutes, which constitute in the main the law now in force in Massachusetts:

ACTS OF 1877.—[Chap. 200.] *An Act to abolish the office of Coroner and to provide for Medical Examinations and Inquests in cases of Death by Violence.* Be it enacted, etc., as follows:

"SECTION 1. The offices of coroner and special coroner are hereby abolished.

"SEC. 2 The governor shall nominate, and by and with the advice and consent of the council shall appoint, in the county of Suffolk not exceeding two, and in each other county not exceeding the number to be designated by the county commissioners as hereinafter provided, able and discreet men, learned in the science of medicine, to be medical examiners; and every such nomination shall be made at least seven days prior to such appointment.

"SEC. 3. In the county of Suffolk each medical examiner shall receive, in full for all services performed by him, an annual salary of three thousand dollars,* to be paid quarterly from the treasury of said county; and in other counties they shall receive for a view without an autopsy, four dollars; for a view and autopsy, thirty dollars; and travel at the rate of five cents per mile to and from the place of the view.

"SEC. 4. Medical examiners shall hold their offices for the term of seven years from the time of appointment, but shall be liable to removal from office at any time by the governor and council for cause shown.

"SEC. 5. Each medical examiner, before entering upon the duties of his office shall be sworn, and give bond, with sureties in the sum of five thousand dollars, to the treasurer of the county, conditioned for the faithful performance of the duties of his office. If a medical examiner neglects or refuses to give bond as herein required, for the period of thirty days after his appointment, the same shall be void and another shall be made instead thereof.

"SEC. 6. The county commissioners in each county shall, as soon as may be after the passage of this act, divide their several counties into suitable districts for the appointment of one medical examiner in each district under this act; and when such division is made, shall at once certify their action to the secretary of the Commonwealth, who shall lay such certificate before the governor and council; but nothing herein shall prevent any medical examiner from acting as such in any part of his county.

"SEC. 7. Medical examiners shall make examinations as hereinafter provided, upon the view of the dead bodies of such persons only as are supposed to have come to their death by violence.

"SEC. 8. Whenever a medical examiner has notice that there has been found, or is lying within his county, the dead body of a person who is supposed to have come to his death by violence, he shall forthwith repair to the place where such body lies and take charge of the same; and if on view thereof and personal inquiry into the cause and manner of the death he deems a further examination necessary, he shall, upon being thereto authorized in writing by the district attorney, mayor, or selectmen of the district, city, or town where such body lies, in the presence of two or more discreet persons, whose attendance he may compel by subpœna, if necessary, make an autopsy, and then and there carefully reduce or cause to be reduced to writing every fact and circumstance tending to show the condition of the body, and the cause and manner of death, together with the names and addresses of said witnesses, which record he shall subscribe. Before making such autopsy he shall call the attention of said witnesses to the position and appearance of the body.

"SEC. 9. If upon such view, personal inquiry, or autopsy he shall be of opinion that the death was caused by violence, he shall at once notify the district attorney and a justice of the district, police or municipal court for the district or city in which the body lies, or a trial justice, and shall file a duly attested copy of the record of his autopsy in such court, or with such justice, and a like copy with such district attorney; and shall in all cases certify to the clerk or registrar having the custody of the records of births, marriages, and deaths, in the city or town in which the person deceased came to his death, the name and residence of the person deceased, if known, or a description of his person, as full as may be for identification, when the name and residence cannot be ascertained, together with the cause and manner in and by which the person deceased came to his death.

"SEC. 10. The court or trial justice shall thereupon hold an inquest, which may be private, in which case any or all persons other than those required to be present by the provisions of this chapter may be excluded from the place where the same is held; and said court or trial justice may also direct the witnesses to be kept separate, so that they cannot converse with each other until they have been examined. The district attorney, or some person designated by him, may attend the inquest and may examine all witnesses. An inquest shall be held in all cases of death by accident upon any railroad; and the district attorney or the attorney-general may direct an inquest to be held in the case of any other casualty from which the death of any person results, if in his opinion such inquest is necessary or expedient.

"SEC. 11. The justice or district attorney may issue subpœnas for witnesses, returnable before such court or trial justice. The persons served with such process shall be allowed the same fees, and their attendance may be enforced in the same manner, and they shall be subject to the same penalties, as if served with a subpœna in behalf of the Commonwealth in a criminal prosecution pending in said court, or before said trial justice.

"SEC. 12. The presiding justice or trial justice shall, after hearing the testimony, draw up and sign a report in which he shall find and certify when, where, and by what means the person deceased came to his death, his name if known, and all material circumstances attending his death; and if it appears that his death resulted wholly or in part from the unlawful act of any other person, he shall further state, if known to him, the name of such person and of any person whose unlawful act contributed to such death, which report he shall file with the records of the superior court in the county wherein the inquest is held.

"SEC. 13. If the justice finds that murder, manslaughter, or an assault has been committed, he may bind over, as in criminal prosecutions, such witnesses as he deems necessary, or as the district attorney may designate, to appear and testify at the court in which an indictment for such offence may be found or presented.

"SEC. 14. If a person charged by the report with the commission of any offence is not in custody, the justice shall forthwith issue process for his apprehension, and such process shall be made returnable before any court or magistrate having jurisdiction in the premises, who shall proceed therein in the manner required by law; but nothing herein shall prevent any justice from issuing such process before the finding of such report, if it be otherwise lawful to issue the same.

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* This sum was changed to four thousand dollars by an act of 1890.

"Sec. 15. If the medical examiner reports that the death was not caused by violence, and the district attorney or the attorney-general shall be of a contrary opinion, either the district attorney or the attorney-general may direct an inquest to be held in accordance with the provisions of this act notwithstanding the report, at which inquest he, or some person designated by him, shall be present and examine all the witnesses.

"Sec. 16. The medical examiner may, if he deems it necessary, call a chemist to aid in the examination of the body, or of substances supposed to have caused or contributed to the death, and such chemist shall be entitled to such compensation for his services as the medical examiner certifies to be just and reasonable, the same being audited and allowed in the manner herein provided. The clerk or amanuensis, if any, employed to reduce to writing the results of the medical examination or autopsy shall be allowed for his services two dollars per day.

"Sec. 17. When a medical examiner views or makes an examination of the dead body of a stranger, he shall cause the body to be decently buried; and if he certifies that he has made careful inquiry, and that to the best of his knowledge and belief the person found dead is a stranger, having no settlement in any city or town of this Commonwealth, his fees, with the actual expense of burial, shall be paid from the treasury of the Commonwealth. In all other cases the expense of the burial shall be paid by the city or town, and all other expenses by the county, wherein the body is found.

"Sec. 18. When services are rendered in bringing to land the dead body of a person found in any of the harbors, rivers, or waters of the Commonwealth, the medical examiner may allow such compensation for said services as he deems reasonable, but this provision shall not entitle any person to compensation for services rendered in searching for such dead body.

"Sec. 19. In all cases arising under the provisions of this act, the medical examiner shall take charge of any money or other personal property of the deceased found upon or near the body, and deliver the same to the person or persons entitled to its custody or possession; but if not claimed by such person within sixty days, then to a public administrator, to be administered upon according to law.

"Sec. 20. Any medical examiner who shall fraudulently neglect or refuse to deliver such property to such person within three days after due demand upon him therefor shall be punished by imprisonment in the jail or house of correction not exceeding two years, or by a fine not exceeding five hundred dollars.

"Sec. 21. The medical examiner shall return an account of the expenses of each view or autopsy, including his fees, to the county commisioners having jurisdiction over the place where the examination or view is held, or in the county of Suffolk to the auditor of the city of Boston, and shall annex thereto the written authority under which the autopsy was made. Such commissioners or auditor shall audit such accounts and certify to the treasurer of the Commonwealth, or the treasury of the county, as the case may be, what items therein are deemed just and reasonable, which shall be paid by such treasurer to the person entitled to receive the same.

. . . .

"Sec. 25. For the purposes of the appointment and qualification of medical examiners and the action of the county commissioners herein provided for, this act shall take effect upon its passage, and shall take full effect on the first day of July next." [Approved May 9th, 1877.]

(Sections 22, 23, and 24, pertaining to the vicarious functions of the coroner, when acting as a sheriff, and also to certain verbal corrections in other statutes, are omitted.)

The principal features in the foregoing act, which constitute the chief difference between the medical examiner system of Massachusetts and the coroner system, are the following:

1. The separation of the medical from the legal duties involved in the investigation of the cause of death, the former being entrusted to medical officers ("able and discreet men, learned in the science of medicine") (Sections 2–9, 16–21, Acts of 1877, Chapter 200; and the latter to properly qualified legal magistrates, Sections 10–14).

2. The abolition of the coroner's office, and also of the jury (Sections 1 *et seq.*).

3. The limitation of the number of medical officers (Sections 2, 6).

This law is the result of a successful attempt to introduce into a New England commonwealth, imbued with a traditional adherence to old and firmly established customs, the plan of continental Europe modified and adapted to a republican form of government.

In Rhode Island a somewhat similar statute was enacted, providing for the appointment, by the governor, of medical examiners in twenty-four districts, for a term of six years.

The town councils also elect "suitable" persons as coroners for three years, and each coroner can appoint a deputy. The coroner may take ante-mortem statements. The expenses of the medical examiners are returnable to the State auditor and are paid by the State. The records of medical examiners are returnable to the State board of health and are published by the board.

In Connecticut the coroner and his jury still exist, but the coroner may appoint a medical examiner in each town. The medical examiner pays fifty cents to each person who first reports a death by violence. The medical examiner may hold an inquest in certain instances.

As may be seen by an examination of Section 8 of the present law of Massachusetts, the medical officer takes the initiative steps in the investigation of each case requiring the exercise of his duties. This method of procedure rests upon the assumption of a natural sequence in the investigation of all cases of death by violence. "The *inquest* is held by the court, and is the inquiry into the facts outside the body; the *examination* is made by the (medical) examiner, and it leads the way to the inquest."

"The purpose of the law is the detection of crime; its method, the division of functions among those properly qualified to perform them."[2]

Financially, the medical examiner system has also proved successful. Comparing the cost of coroner's inquests and views in Massachusetts for three years under the old law (1874, 1875, and 1876) with the cost of similar inquiries under the new law for a like period (1878, 1879, and 1880), as nearly as could be ascertained, the result was for the former period, $63,712.04; and for the latter, $54,509.31; leaving a difference of $9,202.73 in favor of the medical examiner system, notwithstanding an increase of population between the two periods of at least one hundred thousand, and a consequent increase in the amount of work done.[3]

The average expense of the medical examinations ranged from a maximum of $13.08 each in 1886 to a minimum of $11.68 each in 1890.

When considered as a per capita tax upon the population the expense of conducting the medical examiner system is shown to be far less than that of the coroner system.

The budget brought before the Board of Estimate of New York City in January, 1898, contained an item of $239,050 for coroners in the five boroughs, in an estimated population of about three and one-half millions or seven cents per capita of the population for the cost of the coroner system. In the same year in Massachusetts, under the Medical Examiner System, the cost was less than $40,000 in a population of about two and two-third millions, or less than one and one-half cents per capita, for conducting all examinations extending over more than 8,000 square miles of territory. The court expenses were included in this sum.[5]

The chief causes of this diminution in expense are the abolition of the coroner's jury, and the decrease in the number of inquests. In the three years specified under the old law, there were held, in three counties in Massachusetts, one hundred and twenty-four inquests. In three years, under the new law, with a larger population the number of inquests held in the same counties was but seventy-five.

Under the old law the ratio of inquests to cases of all sorts examined throughout the whole State was about forty per cent. Under the medical examiner law the ratio has not been more than twenty-two per cent. "The reasons for this change may be found in the appointment, to fill the offices formerly held by coroners, of men whose education necessarily fits them for the work which they are expected to perform. Under the old law a man found dead, even without the least suspicion of violence, as in simple cases of heart disease or apoplexy, would in all probability be reported to the village coroner, provided the most common hypostatic marks of post-mortem discoloration were observed by a bystander, and interpreted by him as significant of a violent death. Hence the coroner sets in motion the cumbrous machinery of his office. In the first place he sends for a constable. The constable summons a jury. The witnesses come next; and last of all, the nearest physician is summoned, whose evidence finally shows that the man died a natural death. Under the working of the present law the order of procedure is reversed. The medical officer first views the body, and in a case like that just cited he simply reports it as a view. If, however, he believes there is reasonable suspicion of violence, as revealed by the evidence shown him from an external examination of the body, and a personal inquiry of the witnesses, and also by an autopsy, if that be requisite, the case is then reported to the proper authorities for inquest."[3]

After the medical examiner law had been in operation for a period of seven years and a half, the Legislature of 1885 carefully considered certain measures which were proposed for the further improvement of the existing law. These were: the reporting of cases to some central authority who should be entrusted with the compilation, classification, and publication of the returns of the medical examiners; the proper remuneration of medical witnesses at autopsies; and a provision for more definite authority for making autopsies on the bodies of persons found dead.

The first of these duties had been performed very efficiently for seven years by the Massachusetts Medico-Legal Society, an association having as its object "to elevate the official character of the medical examiner, and to assist him in the discharge of his duties; to collect and utilize such facts as have a medico-legal value; and to excite a general interest in the subject of forensic medicine, and to promote its successful cultivation."[4]

The transactions of this society form a valuable contribution to the literature of forensic medicine. It was desirable, however, that the State should have the supervision of the reports of its medical officers, since it could by statutory enactment require a complete report from each examiner, a measure which was clearly impossible in a voluntary association. The following is the substance of the amendments enacted in 1885:

[Chap. 379.] *An Act relating to Medical Examiners.*—Be it enacted, etc., as follows:

"SEC. 1. Section nine of chapter twenty-six of the Public Statutes is amended to read as follows: *Section* 9. In the county of Suffolk each medical examiner shall receive from the treasurer of the county, in full for all services performed by him, a salary of three thousand dollars a year, and the associate medical examiner a salary of five hundred dollars; but if the said associate medical examiner serves in any year more than two months, at the request of either medical examiner he shall, for such service in excess of two months, be paid at the same rate as such medical examiner, and such compensation shall be deducted from the salary of the medical examiner in whose stead he serves. The medical examiners in other counties shall receive fees as follows: For a view without an autopsy, five dollars; for a view and autopsy, thirty dollars; and for travel, at the rate of ten cents a mile to and from the place of view.

"SEC. 2. When a medical examiner deems it necessary to have a physician present at an autopsy as one of the witnesses, as provided in section eleven of chapter twenty-six of the Public Statutes, such physician shall be allowed five dollars for his services. Other witnesses required by law to be present at an autopsy shall be allowed two dollars each.

"SEC. 3. Medical examiners are to transmit copies of the records of all deaths investigated by them to the Secretary of the Commonwealth, annually, before March 1st

"SEC. 4. Fees for returning such copies, twenty cents each for first twenty entries and ten cents for each subsequent entry. Penalty for refusal or neglect ten to fifty dollars.

"SEC. 5. Secretary to provide blank book for records.

"SEC. 6. Secretary to collect returns and tabulate them and report to general court.

"SEC. 7. Medical examiners to report all autopsies to the district attorneys, and affirm their necessity."

The present number of medical examiners is seventy-three, being about one to each 38,000 of the population. Boston has two, with an associate who acts in the absence of either of the others. Each one of the larger cities has also one medical examiner, who also acts in the neighboring towns. The remainder are distributed with a fair degree of uniformity throughout the State.

By an act of 1898 provision was made for the appointment of one associate examiner in each district.

The following statistics relative to the operation of this law are quoted from the registration reports of Massachusetts, for the years 1885 to 1899 inclusive:

TOTAL DEATHS, AND DEATHS BY SEXES, INVESTIGATED UNDER THE MEDICAL EXAMINER LAWS IN MASSACHUSETTS, 1885–1899, TOGETHER WITH THE NUMBER OF AUTOPSIES MADE.

Years.	Males.	Per cent.	Females.	Per cent.	Unspecified.	Per cent.	Totals.	Autopsies.
1885.......	973	76.1	286	22.4	19	1.5	1,278	165
1886.......	1,027	74.5	319	23.2	32	2.3	1,378	202
1887.......	1,191	76.5	350	22.5	15	1.0	1,556	188
1888.......	1,261	76.4	373	22.6	17	1.0	1,651	219
1889.......	1,253	75.8	388	23.4	13	0.8	1,654	216
1890.......	1,303	73.5	449	25.3	21	1.2	1,773	206
1891.......	1,362	74.0	457	24.8	21	1.2	1,840	225
1892.......	1,642	74.3	560	25.3	8	0.4	2,210	272
1893.......	1,678	75.6	530	23.9	13	0.5	2.221	269
1894.......	1,649	76.4	505	23.4	5	0.2	2,159	272
1895.......	1,721	74.3	582	25.1	14	0.6	2,317	271
1896.......	1,773	73.3	638	26.4	5	0.3	2,416	213
1897.......	1,658	72.8	612	26.9	9	0.3	2 279	245
1898.......	1,961	74.0	683	25.8	4	0.2	2,648	230
1899.......	1,788	73.0	661	27.0			2,449	268
Total....	22,240	74.5	7.393	24.8	196	0.7	29,829	

In the following table the same deaths are classified by the modes of death:

SUMMARY OF CASES INVESTIGATED IN MASSACHUSETTS UNDER THE MEDICAL EXAMINER LAWS, BY METHODS OF DEATH.

Years.	HOMICIDE.		SUICIDE.		ACCIDENT OR NEGLIGENCE.		NATURAL AND UNKNOWN CAUSES INCLUDING ALCOHOLISM.		Totals.
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	
1885......	45	3.5	181	14.2	567	44.4	485	37.9	1,278
1886......	47	3.4	157	11.4	678	49.2	496	36.0	1,378
1887......	52	3.3	173	11.1	748	48.1	583	37.5	1,556
1888......	52	3.2	190	11.5	785	47.5	624	37.8	1,651

SUMMARY OF CASES INVESTIGATED IN MASSACHUSETTS UNDER THE MEDICAL EXAMINER LAWS, BY METHODS OF DEATH.—*Continued.*

Years.	HOMICIDE.		SUICIDE.		ACCIDENT OR NEGLIGENCE.		NATURAL AND UNKNOWN CAUSES INCLUDING ALCOHOLISM.		
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Totals.
1889......	51	3.1	199	12.0	792	47.9	612	37.0	1,654
1890......	35	2.0	196	11.1	862	48.6	680	38.3 +	1,773
1891......	60	3.2	187	10.2	866	47.1	727	39.5	1,840
1892......	72	3.2	274	12.4	974	44.1	890	40.3	2,210
1893......	76	3.4	290	13.1	976	43.9	879	39.6	2,221
1894......	68	3.1	270	12.5	975	45.2	846	39.2	2,159
1895......	74	3.2	281	12.1	1,019	44.0	943	40.7	2,317
1896......	74	3.1	318	13.2	1,042	43.1	982	40.6	2,416
1897......	70	3.1	285	12.5	961	42.2	963	42.2 +	2,279
1898......	79	2.9	331	12.5	1,194	45.1	1,044	39.4	2,648
1899......	57	2.3	319	13.0	1,001	48.7	1,072	36.0	2,449
Total ..	912	3.1	3,651	12.2	13,440	45.1	11,826	39.6	29,829

It is a sufficient comment upon this law that more than 40,000 cases of sudden, suspicious, and violent deaths have been investigated under its authority, and in a far more satisfactory, intelligent, and economical manner than could have been possible under the old *régime.*

Samuel W. Abbott.

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[3] Financial Aspects of the Medical Examiner System. Transactions of the Massachusetts Medico-Legal Society, 1881, No. 4, pp. 206, 207.

[4] Constitution of the Massachusetts Medico-Legal Society, Article 2.

[5] The Time and the Hour, Feb. 5, 1898.

EXAMINING AND LICENSING BOARDS.—There is no national authority in the United States that can prescribe standards for degrees or for license to practise the professions. Each State makes its own professional laws. As a result there are almost as many standards as there are political divisions. The desirability of uniform standards throughout the country for admission to professional practice is recognized generally, but varying conditions as to density of population, educational advantages, and general development make it impracticable to hope for the attainment of this end for some time to come. Conditions are such that some States cannot maintain the standards demanded elsewhere, others cannot afford to lower theirs, but needless multiplication is unfortunate. Instead of a separate standard for almost each political division, two or at most three should answer for all. In the first group should come the strongest States, and the standards maintained by these States would act as a stimulus to weaker political divisions.

Thirty years ago the public had little protection from incompetency in professional practice. The bar is said to have been at its lowest ebb. Medical laws were crude and largely inoperative. In several States only were there any acts designed to control the practice of pharmacy and dentistry. There was no law whatever restricting the practice of veterinary medicine. There has been extraordinary progress, specially in the last decade, in restrictive professional legislation, and in the admission and graduation requirements of professional schools throughout the United States. In medicine all political divisions except Alaska now have examining and licensing boards. In view of these facts the growth in professional students is remarkable. From 1888 to 1899 the increase was as follows: theology 24 per cent., law 224 per cent., medicine 84 per cent., dentistry 380 per cent., pharmacy 31 per cent., veterinary medicine 17 per cent.

Power to Confer Degrees.—Low standards in many professional schools are due to a failure to subject the degree-conferring power to strict state supervision. In New York and Pennsylvania the laws now prevent an abuse of the power to confer degrees. In Massachusetts and Vermont bodies formed under the general corporation acts are prohibited from conferring degrees. In Ohio and Nebraska the statutes require only the nominal endowment of $5,000 for a degree-conferring institution. In other States and Territories as a rule any body of men may form an educational corporation with power to confer degrees "without any guaranty whatever that the privilege will not be abused."

This matter has been under discussion recently in various educational bodies, and there is a strong sentiment in favor of a strict supervision by the State of the degree-conferring power.

Preliminary General Education for Degrees.—In New York, high standards in preliminary general education are demanded both for degrees and for licenses, and in each case the question of attainments is determined by a central authority, the University of the State of New York. As a rule in other States medical schools conduct their own entrance examinations, and the tests are often mere matters of form, even though the standards may appear satisfactory on paper. In 1898 21 per cent. of the students of medicine in the United States held either B.A. or B.S. degrees as compared with 53 per cent. of those in theology and 29 per cent. of those in law.

Preliminary General Education for Licenses.—In New York State a preliminary general education equivalent to graduation from a four years' high-school course after a completed eight years' elementary course is prescribed by statute as the minimum standard for license to practise medicine. This standard approximates that required in continental Europe. New Hampshire and Ohio have similar requirements, but they are not so rigidly enforced. California makes the requirements "in no particular less than those prescribed by the Association of American Medical Colleges." Wisconsin requires the elementary education necessary for admission to the junior year including one year of Latin. The statutes of Delaware, Maryland, New Jersey, and Pennsylvania prescribe a "common-school education." Louisiana demands a "fair primary education," Maine a standard of preliminary education approved by the medical board. The rules in Vermont prescribe a high-school course; in Maine a good English education; in Illinois and Iowa less than one year of high-school work; in Virginia "evidence of a preliminary education." In remaining political divisions laws and rules are either silent in this respect or so indefinite as to be of little value.

Length of Professional Courses.—The following table shows great progress, specially since 1885, in the adoption of higher standards for graduation.

	Four years.	Three years.	Two years.	One year.	Not stated.
Medical schools, 1875......	0	3*	72	5	0
" " 1885......	0	5	103	0	0
" " 1897......	99	49	0	2	0
" " 1898......	103	42	0	0	6†
" " 1899......	141	10	2	2	1

* Distinction between medical schools with two- and three-year courses not certain. † Including three medical preparatory schools.

Influence of Medical Societies.—In 1839 the New York State Medical Society resolved that teaching and licensing ought to be separated as far as possible. In 1837 the same view had been advocated in Philadelphia. Further discussion led to a call for a convention of delegates from all medical schools and societies in the United States. The convention was held in New York in 1846, and from it sprang the American Medical Association.

Results of examinations show the importance of separating teaching and licensing. Under the New York laws, for example, 6,349 physicians have been examined, of whom 1,379 or 21.7 per cent., were rejected. In these statistics each candidate who fails is counted as often as examined, but nevertheless so large a per cent. of rejections is astonishing in view of the fact that admission to licensing examinations presupposes the preliminary education required by statute and also graduation with a degree from a registered medical school. Including those unable to meet the requirements for admission to licensing examinations, more than 30 per cent. of all applicants have failed to secure licenses.

The following societies have exercised an important influence in promoting higher standards: Association of American Medical Colleges (1890), American Institute of Homœopathy (1844), National Confederation of Eclectic Medical Colleges (1871), Southern Medical College Association (1892). The first and fourth of these societies prescribe for admission to medical schools a preliminary general education equivalent to one year in a high school; the second and third demand work equivalent to about two years in a high school. All prescribe four courses of lectures in different years as a condition for an M.D. degree, though they give an allowance of one year to graduates of reputable literary colleges and of other professional schools. All tend to improve facilities for teaching, dissection, and clinics. These societies registered in 1900 72, 71, 6, and 11 medical schools respectively.

The American Academy of Medicine (1876) and the National Confederation of State Medical Examining and Licensing Boards (1891) should also be mentioned. The former of these societies has emphasized since 1884 the importance of a proper preliminary education, a graded professional course, and a state licensing examination; the latter has recommended a four years' high-school course for admission to medical schools or an alternative examination representing somewhat less than three years of high-school work.

Medical Sects.—As commonly understood, regular physicians have no distinctive theory or practice; homœopaths treat diseases with drugs that excite in healthy persons symptoms similar to the morbid condition treated; eclectics make use of what they regard as specific remedies, chiefly botanical; physiomedicalists use only botanical remedies, discarding those which are poisonous. In practice these distinctions are not always observed.

In addition to the medical sects to which detailed reference is made, a number of *pathies* flourish in many States unmolested under such names as osteopath, vitapath, electropath, hydropath, divine healer, magnetic healer, Christian scientist, faith curist, mind curist, sun curist, etc. Men and women without preliminary or professional training treat diseases under these or similar systems to such an extent that the health of the people is endangered. These so-called systems are followed with impunity in many States in what seems to be open violation of laws restricting the practice of medicine. This is due largely to the fact that so many statutes lack specific definitions as to what constitutes the practice of medicine, and without these definitions the conviction of such practitioners cannot be secured through the courts.

Osteopathy was "discovered" in 1874. It is based on the theory that "a natural flow of blood is health" and that the bones may be "used as levers to relieve pressure on nerves, veins, and arteries." Oseteopathy is now recognized by law in California, Connecticut, Indiana, Kansas, Ohio, Iowa,* Michigan, Missouri, Montana, Nebraska, North and South Dakota, Tennessee, Vermont, and Wisconsin. Practice of "the system, method, or science of osteopathy" is restricted to licensed physicians and to graduates of "a legally chartered and regularly conducted school of osteopathy." The use of drugs and operations in "major or operative surgery" are not permitted in the practice of osteopathy.

In Georgia, Kentucky, Nebraska, New Jersey, New Mexico, Montana, and West Virginia there are stringent laws against non-medical practitioners. In some other States, like Illinois, they receive such legal protection that any person may treat "the sick or suffering by mental or spiritual means, without the use of any drug or material remedy." Under these conditions any person in Connecticut, Maine, Massachusetts, and New Hampshire is free to practise "the sun cure, mind cure, hypnotism, magnetic healing, Christian science, etc." The greater part of New England seems to be on about the same footing in this respect with the Cherokee nation, Indian Territory, where entire liberty is given to "enchantments in any form." In striking contrast Hawaii inflicts heavy fines on any person convicted of an attempt to cure "another by practice of sorcery, witchcraft, anaana, hoopiopio, hoounauna, hoomanamana, etc."

There is much misunderstanding in this country regarding the duty of the state in relation to the health of the people. It does not consist in discriminating between schools or systems of medicine, but in requiring without prejudice or partiality of all who seek a license to practise for gain on the lives of fellow-beings a minimum preliminary and professional training.

Midwifery.—Special tests for certificates of registration as midwives are required in Arizona, Connecticut, District of Columbia, Illinois, Indiana,* Iowa, Louisiana, Missouri, New Jersey, Ohio, Texas, Utah, Wyoming.

In the following political divisions the provisions of the medical practice acts do not apply to women engaged in the practice of midwifery: Alabama, Arkansas, Florida, Georgia, Idaho, Kentucky, Maine, Maryland, Mississippi, Montana, New Mexico, North Carolina, Rhode Island, South Carolina, Tennessee, Vermont,† Virginia, Washington, West Virginia.

In other political divisions, though there are some special provisions for certain localities, the general acts regulating the practice of medicine make no reference whatever to the practice of midwifery by women.‡ It would seem, therefore, that these laws restrict the practice of midwifery to licensed physicians. Nevertheless a large proportion of the children in these political divisions are brought into the world by ignorant midwives, and as stated by Dr. M. J. Lewi, of New York, many women are physical wrecks through their incompetence. Practically the conditions in political divisions where the laws seem to restrict the practice of midwifery to licensed physicians are little better than in political divisions where the practice of midwifery by women without a license is authorized by statute. There will probably be little change for the better till the midwife receives legal recognition and the practice of midwifery is regulated by definite statutory provisions.

Early Legislation.—The earliest law relating exclusively to physicians was passed by Virginia in 1639, but like the later act of 1736 it was designed mainly to regulate their fees. The act of 1736 made concessions to physicians who held university degrees. In only two of the thirteen colonies were well-considered laws enacted to define the qualifications of physicians. The General Assembly of New York in 1760 decreed that no person should practise as physician or surgeon in the city of New York till examined in physic and surgery and admitted by one of his majesty's council, the judges of the supreme court, the king's attorney-general and the mayor of the city of New York. Such candidates as were approved received certificates conferring the right to practise throughout the whole province, and a penalty of £5 was prescribed for all violations of this law. A similar act was passed by the General Assembly of New Jersey in 1772.

In 1840 laws had been enacted by the legislatures of nearly all the States to protect citizens from the imposition of quacks. Between 1840 and 1850, however, most of these laws were either repealed or not enforced as a result of the cry that restrictions against unlicensed practitioners were designed only to create a monopoly.

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* Either examination or approval of diploma.

† Those practising midwifery without a certificate cannot enforce collection of fee, but this does not apply to the practice of midwifery by women in the town or locality in which they reside.

‡ In Nebraska, North and South Dakota the practice of "medicine, surgery, or obstetrics" without a license is prohibited.

Synopsis of Requirements to 1902.—In the following political divisions medical diplomas do not now confer the right to practise medicine, an examination being required in all cases: Alabama, Arizona, California, Connecticut, Delaware, District of Columbia, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana (after January 1st, 1905), Indian Territory, Cherokee and Choctaw nations, Iowa, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Mississippi, Missouri, Montana, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin.

The following require for admission to the licensing examination:

Alabama, requirements of State Medical Association.

Arizona, diploma from recognized medical school.

California, diploma from legally chartered medical school, requiring in no particular less than the Association of American Medical Colleges.

Connecticut, diploma from reputable medical school.

Delaware, competent common-school education, diploma from legally incorporated medical school.

District of Columbia, diploma of school authorized by law to confer M.D. degree.

Florida, diploma from recognized medical school.

Georgia, diploma from legally organized medical school.

Idaho, diploma from legally chartered medical school.

Illinois, less than one year of high-school work, diploma from approved medical school.

Indiana, diploma from reputable medical school.

Indian Territory, Cherokee nation, diploma from reputable medical school; Choctaw, one term's attendance at reputable medical school.

Iowa, less than one year of high-school work, diploma from recognized medical school.

Louisiana, fair primary education, diploma of recognized medical school.

Maine, diploma of reputable medical school maintaining an approved standard of preliminary education and medical instruction.

Maryland, common-school education, diploma from legally incorporated medical school.

Minnesota, four full courses of lectures at recognized medical school.

Montana, diploma from legally chartered medical school.

New Hampshire, full high-school course, diploma from regularly organized medical school.

New Jersey, common-school education, diploma from legally incorporated medical school.

New York, four years' high-school course or its equivalent, diploma from registered medical school.

North Carolina, diploma from medical school in good standing.

North Dakota, three six months' lecture courses.

Ohio, full high-school course or its equivalent, diploma from legally chartered medical institution.

Pennsylvania, common-school education, diploma from legally chartered medical school.

Utah, diploma from chartered medical school in good standing.

Vermont, high-school course or equivalent and diploma from a United States medical school.

Virginia, evidence of a preliminary education, diploma from medical school.

Washington, diploma from authorized medical school having at least a three years' graded course.

Wisconsin, elementary education equivalent to admission to junior year of a credited high-school.

The following require the licensing examination only: Hawaii, Massachusetts, Mississippi, Oregon, Tennessee, Texas, West Virginia.

The following require approval of medical diploma by duly qualified boards: Kentucky, Nebraska, South Dakota; diploma must evidence four full courses.

The following require either approval of medical diploma or examination by State or other duly qualified boards: Arkansas, Colorado, Indian Territory (Creek nation), Kansas, Michigan, Nevada, New Mexico, Oklahoma, Rhode Island, South Carolina, Wyoming.

The following requiring either approval of medical diploma or examination, admit to examination on: Arkansas, a good literary education; Kansas, four periods of study of six months each; Nevada, five years' practice in the State just prior to act or diploma from a reputable school without the United States; Oklahoma, full course of lectures. Rhode Island approves diplomas of schools that require for matriculation a high-school diploma or its equivalent, and for graduation four regular courses in four different years; Alaska has no law. In Cuba, the Philippines,[*] and Porto Rico[†] the requirements are in process of transition.

The following political divisions have mixed examining boards, that is, the boards are composed of representatives of the several schools of medicine: Alabama, Arizona, Arkansas, California, Colorado, Hawaii, Idaho, Illinois, Indian Territory, Indiana, Iowa, Kansas, Kentucky, Maine, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Jersey, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Virginia, Washington, West Virginia, Wisconsin, Wyoming.

The following have separate examining boards for each recognized school of medicine: Connecticut, Delaware, District of Columbia, Florida, Georgia, Louisiana, Maryland, New Hampshire, New York, Pennsylvania, Texas, Vermont.

Alaska has no examining board.

James Russell Parsons, jr.

EXCELSIOR SPRING.—Onondaga County, New York.

Post-Office.—Syracuse. This spring is located in the city of Syracuse. It was analyzed by Charles A. Goessman in 1868, with the following result:

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	15.24
Calcium sulphate	36.45
Sodium chloride	584.53
Alumina Silica	1.02
Sodium sulphate	13.16
Magnesium chloride	17.69
Magnesium bromide	.15
Total	668.24

Carbonic acid gas present.

This analysis indicates a very potent saline water, with diuretic and slightly aperient properties.

James K. Crook.

EXCOCCURIA. See *Euphorbiaceæ.*

EXERCISE, PHYSICAL. See *Training, Physical.*

EXOPHTHALMIC GOITRE. See the Appendix.

EXPECTORANTS are medicines that are used in catarrhal affections of the larynx, trachea, and bronchi, to modify secretion and facilitate the removal of morbid products.

Until recently our knowledge of their use was founded entirely on careful clinical observations. It had been observed that certain remedies ameliorate cough and increase expectoration in the early stage of acute inflammations of the air passages. Most of them, when given in large doses, produce nausea and vomiting, and a notable depression of the general circulation. They were therefore called *depressant, sedative,* or *nauseant* expectorants. Other remedies had been found to ameliorate cough and diminish expectoration in the latter stage of acute catarrhs, and in chronic catarrhs attended by copious secretion. In large doses many of them cause local irritation, with more or less excitement of the general circulation. Hence they were called *stimulant* expectorants. The recent experiments of Rossbach have confirmed the theory, founded on clinical observation, that some expectorants increase and others diminish secretion. They have rendered our knowledge more precise, and, besides, have established the important fact that some expectorants cause a diminution of the vascularity of the respiratory mucous membrane.

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[*] The assistant secretary to the military governor in the Philippines wrote September 4th, 1899, that "the Spanish law as to admission to practice still governs. In general this requires a diploma from a reputable college, school, or university of such profession or in lieu thereof an examination."

[†] General Davis established, September 30th, 1899, in Porto Rico an examining committee for licenses to practise medicine, midwifery, and professional nursing. Only those with satisfactory credentials are admitted to the examinations.

DEPRESSANT OR SEDATIVE EXPECTORANTS.—*Apomorphinæ Hydrochloras.*—Soon after apomorphine came into vogue, clinicians observed that it exerts a very decided influence in catarrhal inflammations of the air passages. In a short time after its administration is begun expectoration is effected more easily, and the sputa become more copious and less viscid. Usually these effects occur without any noteworthy nausea, or this is observed only after the first dose.

According to the experiments of Rossbach, the expectorant action of apormorphine is due to augmented activity of the mucous follicles; for it caused a very decided increase of the quantity of mucus of the exposed tracheal mucous membrane, when the nerves passing to the trachea had been divided, and all the large blood-vessels supplying this organ had been ligated.

In expectorant doses, apomorphine does not diminish the appetite, nor cause diarrhœa.

Apomorphine is indicated in catarrhal affections of the larynx, trachea, and bronchi, when only small quantities of viscid mucus are secreted; hence, especially in the early stage of bronchitis, when dry, sibilant râles are heard, and when coughing occurs frequently, and is attended by little or no expectoration.

Trustworthy observers state that they have obtained more speedy and more decided success from apomorphine than from all other means in bronchitis, tracheitis, laryngitis, phthisis, and the stage of resolution of pneumonia. Rossbach employed it in pseudo-membranous croup with excellent results, the membranous exudation becoming detached and expelled.

Apomorphine is contraindicated in the above-named affections when moist râles are heard and expectoration is copious. It should never be given when the bronchial tubes are overloaded with secretions which are not expectorated from want of strength.

When a cough is frequent and very severe, and little mucus is secreted, as shown by the scanty, viscid sputum, morphine may be combined with the apomorphine, if the latter do not speedily ameliorate the cough. Morphine does not prevent the action of apomorphine. The combination simultaneously increases secretion and lowers the excitability of the respiratory centre.

No fixed rules can be given as to the dose of apomorphine, on account of the differences in susceptibility to its action, and the great variations in extent and intensity of the catarrhal inflammations of the air passages. For adults, from gr. ss. to gr. i. in twenty-four hours is usually sufficient; but sometimes from gr. iss. to gr. ij. are required. Doses of gr. $\frac{1}{16}$ to gr. $\frac{1}{6}$ may be given every two or three hours. To children apomorphine may be given in doses of gr. $\frac{1}{60}$ to gr. $\frac{1}{10}$, according to their age. At the age of one year the single dose may be gr. $\frac{1}{60}$, and this may be increased by the gr. $\frac{1}{120}$ for each additional year, so that at the age of two years the dose will be gr. $\frac{1}{40}$, at three years gr. $\frac{1}{30}$, and so on. It may be prescribed as follows: ℞ Apomorph. hydrochlor., gr. ss.–i.; acid. hydrochlor. dil., gtt. x.; aq. destill., ℥ iss. M. Sig.: One teaspoonful every two or three hours. The acid is added to prevent the change of color, which rapidly takes place if no acid is added, and the medicine is not dispensed in a dark bottle. A syrup may be added, or, if desirable, each dose may be taken in sweetened water. Morphine may be added to the apomorphine, as in the following formula: ℞ Apomorph. hydrochlor., gr. ss.–i.; morph. hydrochlor., gr. ss.; acid. hydrochlor. dil., gtt. x.; aq. destill., ℥ iss. M. Sig.: One teaspoonful every two or three hours.

Ipecacuanha.—This medicine is frequently employed in catarrhal affections of the air passages, especially in the early stages, when cough is severe and expectoration scanty. It acts most rapidly when given in such doses as produce nausea. As the activity of the mucous glands becomes increased during nausea, it has generally been held that ipecacuanha acts by increasing secretion, but that this takes place only when nauseating doses are used. But it is frequently observed that the symptoms of broncho-tracheal catarrh become ameliorated by doses which do not produce notable sickness.

The action of ipecacuanha is due to the alkaloid emetine, which it contains in small and variable quantities.

Rossbach found that emetine causes a decided increase of the mucus of the trachea, without augmenting the quantity of blood in the mucous membrane. The increase of secretion also took place when the nerves going to the trachea had been divided, showing that it results from a direct action on the mucous glands or on the secretory nerves.

Ipecacuanha is indicated in acute and chronic catarrhs of the air passages attended with scanty and viscid expectoration. It is the expectorant generally employed in the bronchial inflammations of very young, very old, and feeble patients, and is especially applicable when these affections present more or less fever, a dry skin, soreness of the chest, oppressed breathing, painful cough, viscid sputum, and dry râles.

The dose of ipecacuanha varies from gr. ss. to gr. ij., on account of the variable quantity of emetine that it contains, and the differences in intensity and extent of the catarrhal inflammations. If small doses do not speedily cause a decided change in the expectoration, larger ones should be given, so as to induce slight nausea. The syrup and wine of ipecacuanha are given in doses of ♏ x. to ♏ xl.

Antimonii et Potassii Tartras.—Tartar emetic is a very depressing expectorant. When administered in small doses, gr. $\frac{1}{16}$ to gr. $\frac{1}{6}$, at intervals of several hours, it usually produces no immediate effects; but after several doses have been taken a decided action on the heart and secretions becomes manifest, the heart's action becoming slower and feebler, and the secretions of the mucous membranes and skin decidedly augmented. After several days, if the medicine is continued, very marked debility ensues.

Tartar emetic is held to be serviceable in severe forms of bronchitis occurring in robust individuals. It is especially indicated when there are present dyspnœa, flushed face, full and strong pulse, soreness of the chest, with little or no secretion, as shown by the dry, sibilant râles heard on auscultation. On account of its depressing action, which is most evident in weakly persons, it is not a suitable remedy for debilitated, very young, or very old patients. It is contraindicated in catarrhs of the air passages complicated with severe disorders of the alimentary canal.

Tartar emetic is usually administered in doses of gr. $\frac{1}{12}$ every two or three hours. ℞ Antim. et potass. tart., gr. i.; syr. althææ, ℥ ss.; aq. destill., ℥ i. M. Sig.: One teaspoonful every two hours. Sometimes minute doses are given at very short intervals, as by dissolving one grain in five or six ounces of water, and directing a teaspoonful of the solution to be taken every ten minutes until nausea ensues. As soon as this takes place, a marked increase of secretion and expectoration occurs, with decided relief of the soreness of the chest and dyspnœa. The wine of antimony, containing 1 part in 250 parts, is given in doses of ♏ x. to ♏ xl. It is one of the ingredients of the *compound mixture of glycyrrhiza,* which is given in doses of a tablespoonful.

Lobelia is used as an expectorant when bronchial catarrh is complicated with spasmodic contraction of the bronchial tubes, or when a severe cough is attended with difficult breathing, abundant sibilant râles, and viscid sputum. From its utility in such cases it has been inferred that it increases secretion, and at the same time relaxes the bronchial muscles. In spasmodic asthma it is frequently employed with much benefit. But it usually fails to produce any marked effect, unless given so as to cause nausea. The dose varies from gr. i. to gr. v., as an expectorant. Of the tincture (1 in 5) the dose is ♏ v. to ♏ xxv., and of the vinegar (1 in 10) double these quantities.

Pilocarpine.—This alkaloid was found, in the experiments of Rossbach, to cause a very profuse secretion of watery, transparent mucus from the trachea and bronchia, so that moist râles could be heard over all parts of the thorax. Trials of the remedy in cases of bronchitis were attempted, but the action on the salivary and sweat glands, and on the heart, was so disagreeable to the patients that they refused to persevere in its use. The ordinary therapeutic use of this medicine has occasionally been followed by pulmonary œdema.

Alkalies.—It has been frequently observed that bronchial catarrhs improve during the internal use of alkalies. Usually, expectoration takes place more readily, and the sputum is less adhesive. Hence it has been inferred that alkalies increase the bronchial secretion and render it more fluid.

The results of Rossbach's experiments are at variance with this view. After exposing the tracheal mucous membrane of cats, he injected into a vein 2 gm. of carbonate of sodium. The mucous membrane rapidly became pale, presenting a peculiar grayish-white color, and the secretion of mucus gradually diminished, and soon ceased completely. As this result was unexpected, the experiment was often repeated, but the same phenomena uniformly took place. Rossbach was unable to determine the cause of the arrest of secretion. That it was not due to the anæmia was evident from the fact that even more decided anæmia, produced by irritating the nerves distributed to the trachea, did not diminish the secretion of mucus. The local application of solutions of carbonate of sodium, containing from one to two per cent., caused no obvious change in the appearance of the mucous membrane.

The experiments of Rossbach confirm the clinical observation that increased alkalinity of the blood modifies the secretion of mucus, although they contradict the theory that it becomes increased. Perhaps it will be found hereafter, as suggested by Brunton, that the modification of secretion depends upon the quantity of alkali administered, small doses increasing and large ones diminishing the secretion.

If further observation should show that the action of alkalies is the same in man as in Rossbach's experiments, it would follow that alkalies might be used in all stages of bronchial inflammation, and that they would be serviceable not merely to modify secretion, but to diminish the hyperæmia, the chief morbid phenomenon of the disease.

STIMULANT EXPECTORANTS.—*Ammonii Chloridum.*—No medicine is more frequently employed in bronchial catarrhs than this salt. It is held to be suitable when no fever is present, and expectoration is difficult on account of viscidity of the secretion, and to be useless when the sputum is abundant and easily coughed up.

In observations on himself, Wibmer found a very decided increase of the bronchial mucus after doses of gr. viij. to gr. xv., taken hourly. Other careful observers also noticed an augmentation of the bronchial secretion from its use. The experiments of Rossbach seem to show a different mode of action. Under the influence of the salt the tracheal mucous membrane became anæmic, and the secretion of mucus gradually ceased. The utility of chloride of ammonium in catarrhs of the air passages may therefore depend upon a favorable modification of the vascularity of the mucous membrane, not merely upon a change of the quantity of the secretion.

Chloride of ammonium is indicated in bronchitis after the fever has subsided. When secretion is very viscid, it is frequently combined with ipecacuanha, or with minute doses of tartar emetic. To adults it is given in doses of gr. v. to gr. x. every two or three hours. ℞ Ammon. chlor., ℈ij. to ℈iv.; ex. glycyrrh., ʒ ss. to ʒ i.; aq. destill., ℥ iv. M. Sig.: One tablespoonful every three hours. The extract of liquorice of this prescription renders the taste of the salt less disagreeable. If slight elevation of temperature exist, or if dry râles be heard, ipecacuanha may be added, or, in robust subjects, tartar emetic as follows: ℞ Ammon. chlor., ℈iv.; ex. glycyrrh., ʒ ss.; syr. ipecac., ʒ ij. to ʒ iv.; aq. destill. ad ℥ iv. M. Sig.: One tablespoonful every three hours. ℞ Ammon. chlor., ℈iv.; antim. et potass. tart., gr. ss. to gr. i.; ex. glycyrrh., ʒ ss.; aq. destill., ℥ iv. M. Sig.: One tablespoonful every three hours.

Ammonii Carbonas.—This salt is employed in bronchitis, catarrhal pneumonia, and croupous pneumonia, when the fever has subsided or abated, and the general condition of the patient requires the use of stimulant remedies. It is held to act on the mucous glands of the air passages, thus increasing the quantity of mucus and rendering it more fluid. At the same time it stimulates the respiratory centre when given in tolerably large doses, and thus augments the efficiency of the expulsive efforts. The recent researches on the physiological action of this salt have fully confirmed the theory held in the early part of the last century that it possesses great utility in pulmonary affections, because it stimulates the nervous system, and hence enables debilitated patients more readily to cough up accumulated masses of mucus.

Usually it is given to adults in doses of gr. v. to gr. x. every two or three hours. On account of its pungency it is combined in prescriptions with gum arabic and sugar or liquorice. ℞ Ammon. carb., ℈ij. to ℈iv.; pulv. acaciæ, sacch. albi, āā ʒ ij.; aq. menth. pip. ad ℥ iv. M. Sig.: One tablespoonful every three hours.

Aqua Ammoniæ and *Spiritus Ammoniæ Aromaticus*, in appropriate doses, may be used as stimulant expectorants, to increase secretion and excite the respiratory centre.

Scilla.—Squill is perhaps more frequently used than any other expectorant in the advanced stage of acute bronchitis and in chronic bronchitis, especially when secretion, though not scanty, is tenacious, and hence expectorated with difficulty. The investigations on the physiological action of squill have not fully explained its expectorant action, no special modification of secretion of mucus having been observed. But they have conclusively established that squill modifies the action of the heart in the same manner as digitalis, rendering its contractions slower but more forcible. The general blood pressure, therefore, becomes increased, and the circulation in the respiratory mucous membrane accelerated. It is hence quite probable that catarrhal symptoms subside as the result of the improved pulmonary circulation. The fact frequently observed that squill is most effectual in bronchial catarrhs with obstructive heart disease, strongly supports this view.

Squill is usually administered in the form of the syrup, in doses of ♏ xx. to ♏ xl. every two or three hours. It is often combined with ipecacuanha and camphorated tincture of opium when secretion is scanty and the cough severe. ℞ Syr. scillæ, syr. ipecac., tinct. opii camph., āā ℥ i. M. Sig.: One teaspoonful every three hours.

Senega.—The use of senega as an expectorant is based upon careful clinical observation, although it has been found to cause cough and expectoration of mucus in healthy persons. Experience has shown that it is most useful in the second stage of acute bronchitis, in chronic bronchial catarrh, and in pneumonia in the stage of resolution, when the symptoms indicate that the bronchial tubes contain large quantities of secretion. It is held to be especially serviceable when the sputa are muco-purulent and the power to expectorate is small.

The use of senega in bronchitis and pneumonia is indicated by the presence of numerous moist râles, purulent or muco-purulent expectoration, and oppression of the chest. It should not be administered as long as the temperature is much above the normal. It is, however, doubtful whether senega tends to increase fever, as it has been found experimentally that saponin, which appears to be identical with the active principle of senega, lowers the temperature.

The preparations of senega most frequently used are the fluid extract and the syrup, in doses of ♏ x. to ♏ xx. and ʒ i. or ij., respectively.

Oleum Terebinthinæ.—It has frequently been observed that oil of turpentine diminishes the sputum in various forms of bronchitis with profuse secretion, and lessens the offensive odor of the expectoration in fœtid bronchitis and pulmonary gangrene. That it really lessens the amount of secretion in bronchial catarrhs was conclusively shown by Jürgensen (Ziemssen's "Handbuch," Bd. v., p. 182), who in numerous cases carefully measured the quantity of sputum, and constantly found a diminution. The clinical observations have been fully confirmed, and the mode of action of oil of turpentine plausibly explained by the investigations of Rossbach. In carefully conducted experiments he found that the oil exerts a very decided influence on the mucous membrane of the air passages. When a current of air which had passed through oil of turpentine, so as to become loaded with it, was applied to a part of the mucous membrane, the secretion of mucus gradually diminished, and finally ceased, and the membrane became very dry. A watery solution containing from one to two per cent., dropped upon the mucous membrane, caused an immediate increase of secretion and notable anæmia.

Oil of turpentine, when taken internally, is partly eliminated by the respiratory mucous membrane. In passing through the membrane it doubtless exerts an irritant or stimulant action on the blood-vessels, in consequence of which they contract. This contraction of the vessels is soon followed by absorption of exudation and lessened activity of the mucous glands. The decided improvement observed in the odor of the sputum in fœtid bronchitis and pulmonary gangrene is doubtless attributable to the antiseptic power of oil of turpentine, by which it arrests the process of decomposition in the secretions. Rossbach supposes that its antipyretic action, its property of slowing respiration, and its depressing effect on sensory nerves may contribute to its therapeutic utility.

Oil of turpentine is indicated in all forms of bronchitis with free secretion, but especially when the expectoration is profuse, muco-purulent, and fœtid.

It is usually given in doses of gtt. v. to gtt. xx. every two or three hours. Frequently it is administered in emulsion, as follows: ℞ Olei terebinth., ʒ i.; vitellum ovi unius; syr. aurant., ℥ ss.; aq. cinnam. ad ℥ iv. M. Sig.: One tablespoonful every three hours. Jürgensen administers the oil in doses of about twelve drops six times daily in several ounces of milk. If the oil is taken in capsules, a small quantity of milk may be drunk after each one, in order to prevent irritation of the stomach.

Terpin Hydrate, $C_{10}H_{16}3H_2O$, is a hydrate of oil of turpentine that often forms when the oil is in contact with a small quantity of water for some time. On a large scale it is obtained by mixing oil of turpentine with alcohol and nitric acid. It is in the form of large colorless crystals, having no odor and only a very slight aromatic taste. It dissolves in 250 parts of water at 15° C., in 32 parts of boiling water, and in 10 parts of alcohol.

Terpin hydrate was introduced by R. Lepine, of Lyon, as an effective remedy for chronic bronchitis. He had used it in several hundred cases, and had observed that doses of 0.2 to 0.6 (gr. iij. to gr. ix.) daily rendered the sputa less tenacious and more copious, and facilitated expectoration. In cases of bronchorrhœa larger doses, 1.5 (gr. xxij.) daily, lessened the quantity of sputum. Such doses also increased the action of the kidneys, but, when these organs were normal, never caused albuminuria or hæmaturia.

The observations of Lepine have been corroborated by a number of clinicians in large hospitals. Thus Germain Sée found terpin hydrate very effective in catarrhal affections of the respiratory mucous membrane, the morbid secretion gradually diminishing under its prolonged use. In catarrhal forms of phthisis, he observed that the muco-purulent secretion lessened and often entirely ceased. He employed it also to arrest the hæmoptysis of the early stage of phthisis, and held it to act more rapidly than ergotin.

Dr. Manasse, of Berlin, found terpin hydrate very useful in whooping-cough, of which he treated forty-one cases, varying in age from nine months to twelve years. Every case was carefully observed, the frequency and severity of the paroxysms being noted daily. To children under one year of age he sometimes gave as much as 1.5 (gr. xxij.) daily, and never observed any injurious action on the digestive or urinary apparatus. And in no case, when 2.5 to 3.0 daily were given to older children, did the urine become albuminous or bloody. As a rule, in four or five days the paroxysms were less numerous and always less severe. The bronchial catarrh, which was present in most cases, diminished more rapidly than usual, and finally disappeared entirely. All the cases treated with terpin hydrate recovered. The medicine was given in the form of powder as follows:

℞ Terpini hydrat. 5.0–10.0 (gr. lxxv. to gr. cl.). Div. in part. æqual. No. x. S.: One powder three times daily.

The following formulæ have been recommended:

℞ Terpini hydrat. 3.0 (gr. xlv.); sacch. alb., mucil. acaciæ, āā q. s. M. ft. pil. No. xxx. S.: One to four pills three times daily. ℞ Terpin. hydrat. 2.0 (gr. xxx.); spiritus (alcohol), aq. dest., syr. menthæ pip., āā 50.0 (ʒ xiij.). M. S.: One tablespoonful from three to six times daily.

Copaiba.—Although the action of this agent on the mucous membrane of the air passages has not been investigated experimentally, it seems highly probable that it is analogous to that of oil of turpentine. Numerous careful observers have found it useful in chronic and in fœtid bronchitis, and some of them state that it is equalled by no other medicine in catarrhs attended with profuse expectoration. It is usually given in emulsion in doses of ♏ x. to ♏ xx. from three to six times daily.

Pix Liquida.—Tar seems to be useful in chronic catarrh of the bronchi and in phthisis, when copious secretion is taking place. It often lessens the expectoration, eases the cough, and diminishes the oppression of the chest. Usually it is administered in the form of the officinal syrup, of which the dose is ʒ i. to ʒ iv. The following formula was recommended by Adrian: ℞ Picis liq., vitell. ovor., āā 25.0; glycerini, 50.0. M. Sig.: One or two teaspoonfuls from three to six times daily.

Eucalyptol.—This volatile oil has recently gained some repute in bronchorrhœa and fœtid bronchitis. It is a powerful antiseptic. Taken internally, it is eliminated by the kidneys and the lungs, and seems to act upon the respiratory mucous membrane in the same manner as oil of turpentine. It is administered in doses of gtt. v. to gtt. xv. in capsules or emulsion.

Grindelia has lately been strongly recommended in spasmodic and catarrhal affections of the bronchial tubes, and in whooping-cough. According to some of the published reports, in some instances "it acts like a charm, instantly controlling the cough, and relieving the tickling in the throat and bronchial tubes." The fluid extract is given in doses of ♏ x. to ♏ lx.

Ammoniacum, benzoic acid, myrrh, balsam of Peru, balsam of tolu, garlic, and *sanguinaria* have been employed in bronchial catarrhs with good effects. They are, however, at the present time, rarely prescribed.

MORPHINE AND ATROPINE.—These alkaloids are so useful in diseases of the air passages, and so frequently administered simultaneously with some of the expectorants, that a very brief consideration of their mode of action is here appropriate.

Atropine is in constant use in phthisis to arrest night sweats. Many observers have noticed, during its administration, a decided lessening of expectoration and cough. This effect was usually ascribed to an action on the vagi in the lungs, and on the mucous glands, which were supposed to become affected in the same manner as the sweat glands. In experiments, Rossbach observed that atropine acts very strongly upon the tracheal mucous membrane. He invariably found that the membrane, which had been secreting normally and was very moist, became absolutely dry. Gradually very decided hyperæmia supervened; yet no secretion occurred for an hour or longer, and afterward returned very slowly and feebly. The persistence of the dryness, notwithstanding the hyperæmia, proved that atropine acts on the mucous glands or secretory nerves. It is therefore an appropriate remedy in bronchial and pulmonary diseases, when the cough depends upon copious secretion in the trachea and bronchial tubes.

Morphine lessens cough in two ways—by diminishing secretion, and by lowering the excitability of the respiratory centre.

Rossbach observed that, normally, after removal of the mucus from the tracheal mucous membrane, about twenty seconds passed before the membrane was again completely moist. But after subcutaneous injections of morphine, the membrane did not become equally moist before the lapse of from eighty to one hundred seconds.

Cough may be very readily produced by slightly irritating the normal mucous membrane of the larynx and trachea, especially near the bifurcation of the bronchi. An hour after injecting morphine, Rossbach found that only very severe irritation produced cough, while gentle irritation had no effect.

When used simultaneously, both alkaloids act, lowering the excitability of the respiratory centre and notably lessening secretion. In chronic catarrhs, emphysema, and phthisis, with copious expectoration, they have been found of great utility. In phthisis, when the expectoration comes from cavities, no very marked diminution can be produced.

As a rule, the two alkaloids should be prescribed separately—atropine to be taken only in the evening, between six and ten o'clock; and morphine, in very small doses, during the day.

Codeine.—Codeine has recently come into use as a means of allaying cough. According to numerous reports, it is generally as effectual as morphine or the preparations of opium. Often it has been observed that the cough of mild forms of bronchitis ceased in a few days. But its principal advantage is that it does not depress the functions of the alimentary canal. The use of morphine is usually followed by a diminution of appetite, and often by constipation. Codeine, while it allays the cough, does not interfere with the appetite, or with the normal action of the bowels. This has been especially observed in phthisis, in which codeine was found to mitigate the cough without lessening the desire for food. When, to test the difference in action, Dover's powder was given to patients that had been taking codeine, the appetite, which had improved under the use of codeine, diminished again, showing the decided superiority of codeine. It has been found to be very useful in the bronchitis of children, and, in appropriate doses, has been given to infants, without any unpleasant effects.

Codeine should therefore be preferred to morphine in all cases of severe cough in which it is necessary to maintain a good appetite, as in bronchial catarrhs complicating chronic wasting diseases, in children, and in persons subject to constipation. Especially, should codeine be preferred to morphine to relieve the cough of phthisis; for if the means used to mitigate this tormenting symptom interfere with digestion and nutrition, little hope of saving life can be entertained.

The salts of codeine commonly used are the sulphate, phosphate, and hydrochloride. They all readily dissolve in water, and are usually prescribed in aqueous solution with a small quantity of syrup, or together with sugar in the form of powder. The dose for adults is gr. $\frac{1}{4}$ to gr. $\frac{3}{4}$; for infants, gr. $\frac{1}{60}$; and for children three or four years of age, gr. $\frac{1}{15}$ to gr. $\frac{1}{10}$, from three to five times daily.

Heroine, a derivative of morphine—diacetyl morphine—is rapidly coming into use as a cough remedy. It is a white powder, having a bitter taste, not easily soluble in water, but readily soluble in water acidulated with a few drops of acetic acid. Its salt, heroine hydrochloride, is soluble in two parts of water.

Heroine was introduced in 1898 by Prof. H. Dreser, of Elberfeld. In experiments upon animals Dreser had found that heroine notably slows the respiratory process and renders it deeper. He administered it in doses of 0.01 to patients having cough and found it to give much relief.

Harnack in experiments upon dogs observed also notable slowing of respiration, but it became decidedly weaker; hence he concluded that heroine is more poisonous than morphine and should not be given in doses larger than 0.005. Strubbe experimented upon dogs, cats, and rabbits, and obtained results agreeing essentially with those of Dreser. Sartissen, on the contrary, found the respirations shallower, although slower.

Numerous clinical observations of the action of heroine have been made in hospitals and in private practice, and with nearly uniformly good results. Perhaps the most careful observations are those of Brauser, made in Ziemssen's clinic. In eighty cases an accurate record was kept, and control trials were made with simple sugar, codeine, and morphine. The cases treated embraced phthisis, acute and chronic bronchitis, croupous pneumonia, pleuritis, cardiac dyspnœa, and patients having pain from other causes. In the great majority of the cases heroine promptly lessened the cough. Usually this result followed when 0.005 was given in the morning and at noon, and 0.01 in the evening. In most cases the respirations were slowed, often from five to eight in a minute, sometimes only two or three. In the same patients sometimes the respirations were lessened, sometimes uninfluenced. In about one-third of the cases no change in the frequency of respiration could be observed, especially in cases not presenting any marked acceleration. This occurred, however, also when the respiratory process was greatly accelerated, especially in pneumonia. In some cases of cardiac dyspnœa the action of heroine was notably beneficial, the breathing becoming slower and more nearly normal.

From these and numerous other cases Brauser concluded that heroine acts as promptly and effectually as morphine in relieving cough, and that it is very useful in dyspnœa, though not certain, giving decided relief in only about two-thirds of the cases treated.

Floret observed that heroine when given together with apomorphine produced disagreeable effects—vertigo and headache. In phthisis, when not far advanced, the combination of heroine and duotal (heroine 0.005–0.01; duotal 0.5, given four times daily) was followed by general improvement and a notable retrogression of the objective symptoms. *Samuel Nickles.*

EXPECTORATION. See *Sputum.*

EXPERT MEDICAL EVIDENCE.—In the last few years the medical expert witness has figured prominently in many celebrated criminal and civil actions. At first his evidence was received by the court and jury with the deference and respect which honesty, intelligence, and learning always inspire. But in more recent times many things have conspired to place the medical expert witness on a much lower plane than he formerly occupied. The principal reasons for this degeneration may be found in the seeming partisanship of some of those who take the stand as experts; the employment of witnesses who are qualified neither by education nor by experience to act as experts; and the opinion, which has become impregnated in the public's mind, owing to the methods of procedure followed by the attorneys in the case, that the most able experts can be hired to swear to diametrically opposite conditions of facts. All of these things together have operated to prejudice the people, and consequently the jurors, against the introduction of medical expert evidence. Indeed in more than one instance talesmen have been rejected as jurors because of their avowed disbelief in, and determination to reject, all expert evidence.

Medical expert evidence should, theoretically, often be of inestimable service in that it is perhaps the only way in which certain facts vital in importance can be brought to the attention of the jury, and the relation of these facts to the case explained. A medical expert is one who by study and experience has become especially learned or skilled in some branch of medical science and whose judgment and opinions therefore are sounder than those of the average physician. It is of the greatest importance, therefore, that one who poses as an expert should actually be qualified to act as such. Attorneys are not always careful in the selection of their medical witnesses, either from ignorance or because they cannot or will not pay the fees which the expert generally demands, and they often call to the stand physicians of excellent general knowledge but who are not at all prepared to meet the ingenious questions of a skilful cross examination. Again, the fault is with the physician who, tempted either by the pecuniary reward for his services or by the opportunity of achieving a certain degree of notoriety, places himself in a position which his limited knowledge and experience are inadequate to support. His answers to questions clearly show, to the expert at least, that he does not possess an intimate knowledge of his subject, and when confronted by an expert witness there often follows a flat contradiction of opinion. The evidence of the medical witness, like the evidence of any other witness, is addressed to the jurors and is for their consideration. They do not always know who are experts and who are not; so generally regard all the medical witnesses as possessing the same degree of skill and ability. They cannot, of course, be expected to detect the ignorance on the part of a medical witness which is so apparent to the expert. They simply recognize the contradictions which necessarily arise in a conflict between ignorance on the one hand and knowledge on the other; and confusion of mind and doubt naturally follow. For this reason medical evidence is sometimes completely ignored by the jurors and falls greatly in public estimation. The medical witness should never allow himself to act in the dual rôle of witness and associate counsel. The spectacle is seen at nearly every trial of prominence, and in many others, of one or more physicians sitting close to counsel, taking copious notes of the evidence, formulating questions to be used in direct and cross examinations, looking up references and in reality conducting the medical part of the prosecution or defence, and then when their turn comes taking their place in the witness chair to act as experts. Associate medical counsel is often of valuable assistance. No matter how skilful an attorney may be or how thoroughly he has studied his case, a well-trained medical mind can point out to him many features, and give him many suggestions which would otherwise escape him. A counsel often strengthens his case by the help of a medical associate and the employment of a physician as such is perfectly proper from every standpoint. But for such a one to take the stand as a witness stamps him as a partisan to the jury. It cannot help but regard him as a biassed witness, who comes prepared to fight for "his side" of the case. The influence of his testimony is, of course, much less than that of the witness who confines himself to his duties as a witness only. It is, of course, incumbent on a physician who purposes to act as an expert witness to point out the medical aspects of the case to counsel and to suggest such questions for the direct examination as will enable him to express his investigations, deductions, and opinions in his own way and to his best advantage. He may also with propriety suggest the general course of the direct and cross examination of other experts, but further than this he should not go and cannot go without seriously compromising himself as an unbiassed witness. Even the construction of hypothetical question which generally terminates the expert witnesses' direct examination, should not be performed by him. He may point out to counsel the medical facts which should be incorporated in the question. But should the fact be elicited from the witness that he was the author of the question he has just replied to, the force of his answer is lost and his value as a witness is greatly diminished.

It generally appears to the public, particularly in notorious trials, that a certain number of experts called by one side swear positively and diametrically opposite to the experts called by the other side. It is this feature which has called down so much and so unfavorable criticism upon the medical expert witness and upon the value of expert testimony in general. A great deal has been written and much thought given to the formation of a plan by which medical expert testimony can be employed without the objectionable features which now mar it and yet preserve the constitutional rights of the prosecution or defence. It is not a simple question for solution, and none of the methods which have so far been advocated seems to fulfil all the requirements of the case. The fault lies mainly with the attorneys and not with the experts. It seems, at first glance, as if the experts on one side flatly contradict the experts on the other. This may be the case in some instances, for two minds working upon the same assumption may come to different conclusions. But it is not generally so, at least, in medicine. In trials, as they are conducted at the present time, there is no possible chance for an agreement of the experts. The witnesses for the two sides are not asked to give opinions based upon the same assumptions; each counsel has his own hypothetical question which differs from that of his opponents as night differs from day. They are based upon absolutely different assumptions of facts, and the answers given are in accordance with the assumption in each question. Should the opposing counsel exchange hypothetical questions, the answer of every expert witness would be changed also.

The expert opinions are of no value at all unless the assumptions contained in the hypothetical question are proved to be true. If the jury believes the assumptions in one hypothetical question, then the expert opinions based thereon are worthy of consideration; otherwise not. If these points were generally understood, it would be comprehended that the seeming clashing of expert opinions is in reality nothing of the sort, but that the opinions given are nearly what they claim to be, honest answers to absolutely different questions.

Another feature which stands in the way of obtaining the best expert evidence is the purposeful and wilful interference with which one attorney in the action foils every attempt, to the best of his ability, of the expert called by his opponent to obtain those details of the case which are requisite for the establishment of a sound medical opinion, while every facility is freely granted for every investigation his own experts desire to make. Thus a man on trial for murder pleads insanity. The experts called by his counsel have frequent interviews with the accused, and on these occasions he talks freely and openly and submits willingly to any examination they may desire. The relatives and friends communicate the family history, the personal history, and any other facts which may be of service to the examiner, and he comes into court well informed in every detail of the medical features of the case. But how is it with the expert called by the state? Has he had an equal chance for rendering a truthful solution of the question? He certainly has not. When he interviews the accused he is not welcomed. The prisoner sees in him a man who is to assist in taking his life and therefore gives as little information as he can. He is often carefully coached as to the replies he is to make to certain questions, and the friends and relatives either give no information at all or else give that which is either false or misleading. As a rule the examiner obtains but little more information than can be derived from a study of the physical symptoms, which in many cases is absolutely insufficient for a satisfactory diagnosis. These defects in the present system of expert medical evidence are frankly admitted by both physicians and lawyers, and any method by which an unbiassed and uncontradicted expert opinion could be obtained without infringing upon personal rights, would be gladly welcomed by both professions. The plan most constantly urged is the appointment of a board of experts commissioned by the court to make a physical or mental examination, or both, as the case may be, and then to report the result of its findings to the court and jury. This seems simple, and no doubt it would prove to be a most satisfactory method if the question could be ended then and there. But it would not end there. A party to an action has a right to call any witness whose testimony will tend to prove his allegations. Should the report of the commission of experts be adverse to his interests he may call his own experts, who may not agree with the commission and then there is the same old story of expert against expert.

A most simple and effective method and one which, while it preserves the rights and liberties of all the parties concerned, would result in more harmonious expert evidence, is the following: Each party to the controversy shall select such expert or experts as they may desire. When this has been accomplished to the satisfaction of both parties, it shall be obligatory that every examination of the plaintiff or defendent, as the case may be, shall be made in the presence of all the experts together and shall be participated in by all the experts. And that at each examination counsel for both parties shall be present, and an official stenographer who shall report verbatim what was said and also what was done by each examiner in the line of his examination, and that a copy of the report of each examination shall be furnished to each counsel and to the court to be used by counsel on the direct and cross examination of each expert; and that all information relating to the question supplied to or acquired by any expert shall be furnished to every other expert. By this means all the experts will have an equal knowledge of the case and each will have every opportunity for forming a correct opinion. The stenographer's report, showing each expert's complete examination, in the hands of counsel will do more to secure a unanimity of opinion than anything else could do.

When everything has been said, however, and the question has been considered from all its standpoints, it must be admitted that expert medical testimony, which should be a valued, scientific, and honored method of assisting justice to know the truth, has been prostituted by those attorneys who are willing to use any means to save a client or secure a verdict, and by physicians who are willing to lend themselves for such a purpose. The medical expert should be regarded as a scientist, and expert evidence should be received by court and jury with respectful consideration. It is the medical expert himself who is to blame. When he recognizes this fact the remedy will quickly follow. The medical profession is respected everywhere but in the courts. Let it be seen to that it is respected there also.

Graeme M. Hammond.

EXTRA-UTERINE PREGNANCY.—By extra-uterine pregnancy we mean those instances in which the fertilized ovum is arrested somewhere in its course from the ovary to the uterus and there undergoes development. The term ectopic gestation has a somewhat broader meaning than extra-uterine pregnancy, and has reference not only to such cases as mentioned above, but also to those instances in which the pregnancy occurs in some abnormal diverticulum of the uterus.

Until as recently as 1883 the condition was of interest chiefly from its pathological standpoint; and few or even no cases were recognized clinically. But from that date, at which time Tait operated on his first case of ruptured tubal pregnancy, the clinical interest in the affection has been markedly increasing, as is shown by the decided increase in the literature on the subject and the apparent increase in the frequency of the condition.

FREQUENCY.—Before extra-uterine pregnancy came to be recognized clinically and at autopsy, observers were much misled as to its frequency; and consequently such statements as that made by Hennig, in 1876, to the effect that the affection is so rare that the directors of large obstetrical clinics might never see a case of it, were not to be wondered at. On the other hand, the data now available might readily lead one to suppose that the frequency has markedly increased since that time. Thus, for example, Parry, in 1876, was able to collect only five hundred cases that had been reported up to that time, while in 1892 Schrenck collected six hundred and ten cases which had been reported in the five previous years.

This apparent increase in frequency has also been noted in the experience of individual operators and in single clinics. The increase, as a matter of course, is more apparent than real; it is due unquestionably to our improved methods of diagnosis and greater knowledge of the subject.

ETIOLOGY.—So many theories have been advanced to explain the occurrence of extra-uterine pregnancy that it is impossible to make any very definite statements as to its etiology. J. Whitridge Williams, after a most exhaustive review of the literature, gives the following classification, which, although somewhat complicated, is probably the best which, in the present state of our knowledge, can be offered. He divides the etiological theories into four groups:

I. *Conditions which Interfere Mechanically with the Downward Passage of the Ovum.*—(*a*) Peritoneal adhesions. This is one of the earliest explanations for the occurrence of extra-uterine pregnancy and is still held by many to be the principal one. The adhesions act either by directly compressing the lumen of the tube, or by interfering with its muscular action; both of which conditions are sometimes verified at operation or at autopsy.

(*b*) Tubal polypi, projecting into the cavity of the tube and therefore impeding the downward passage of the ovum, have been found by certain operators. Williams in his analysis is of the opinion that only a few of the cases in which this condition was stated to have been the cause are at all convincing, and he agrees with Ahlfeld in thinking that in many cases the "tubal polypi" are merely decidual ingrowths, the result rather than the cause of the extra-uterine pregnancy.

(*c*) Tumors of the tube wall and in some instances tumors of adjacent organs have been said to play a similar part by compressing the lumen of the tube.

(*d*) Salpingitis. The suggestion was made by Schroeder and Tait that inflammation of the lining of the tube so damaged the cilia of the mucous membrane that a downward current was no longer produced and consequently no obstacle was offered to the entrance of the spermatozoon into the tube. This view presupposed that fertilization normally took place in the uterus and that the ciliary currents favored a meeting of the male and female cells at the fundus. We know now, however, that the currents throughout the utero-tubal tract run in the same direction, viz., from above downward, that the spermatozoon has to work against the stream from the time it enters the internal os, and that as fertilization normally takes place in the tube all pregnancies are primarily tubal. Microscopic examination, furthermore, has not confirmed the view put forward by Schroeder and Tait, for in these cases of tubal pregnancy ciliated epithelium is usually found covering the mucosa.

(*e*) Obstruction by twin ova. The comparative frequency of the coexistence of extra- and intra-uterine pregnancy has led certain observers to suggest the possibility of the mutual interference of twin ova as a cause for tubal pregnancy.

(*f*) Fœtal twisting of the tube. While the Fallopian tube in adult life is a comparatively straight canal, that of the fœtus is a convoluted one. These convolutions may persist in adults, and may then stand in causative relation to certain forms of tubal disease, notably extra-uterine pregnancy.

(*g*) Diverticula of the lumen of the tube. The occasional presence of these diverticula was demonstrated by Williams in 1891, and he at that time suggested that they might be shown to act as a causative factor in certain cases of tubal pregnancy. While he is still of the opinion that such a state of affairs *may* exist, he admits that he has been misled by some of his specimens in which he found the fertilized ovum lying outside of an apparently intact tubal lumen. Since Peters has demonstrated in the uterus that the ovum burrows down beneath the epithelium, which finally closes to form an intact surface over it, there is reason to believe that the same thing occurs in the tube; thus explaining the fact that in early cases of tubal pregnancy the ovum may be entirely outside of the lumen of the tube.

(*h*) Puerperal atrophy of the tube. Dührssen has reported cases of extra-uterine pregnancy which have occurred in an incredibly short time after labor, in some instances even while the mothers were nursing their children. In these instances he considers the cause to be a puerperal atrophy of the tube which interferes with its peristalsis. In one case operated upon by the author this factor may have been present. The pregnancy probably began six weeks after the birth of a dead child, and tubal rupture took place six weeks later.

(*i*) External migration of the ovum, which is quite a common occurrence in extra-uterine pregnancy, has been given as a causative factor by some investigators, they holding that the fertilized ovum in its transit through the peritoneal cavity attains such a size that its transmission through the opposite tube is an impossibility.

II. *Abnormal Conditions Resulting from Inflammatory Diseases of the Tubes, Ovaries, and Pelvic Peritoneum.*—Mention has already been made of the part that the absence of cilia is supposed to play in the causation of extra-uterine pregnancy and little need be added to this statement. Most cases of tubal pregnancy will reveal a history of pre-existing inflammatory trouble, and it is the rule to find some other abnormality besides the pregnant tube at operation or autopsy. This has given rise to the statement that an inflammatory condition of the pelvic organs is the principal cause of extra-uterine pregnancy, but, unfortunately for the correctness of this statement, actual examinations, at operation or at autopsy, show that such an inflammatory condition is not present in all cases. On the other hand, the fact that tubal pregnancy occurs repeatedly in women suffering from gonorrhœa certainly favors the above statement.

III. *Physical and Developmental Conditions which Favor Decidual Formation in the Tubes.*—This theory was originated by J. C. Webster, who was not satisfied with the numerous etiological views that had been advanced. He recalls the fact that as the uterus and tubes are both developed from the same embryonic structure, the Müllerian ducts, there is no reason why the ovum should not be implanted upon the upper as well as upon the lower portion of the tract. Normally, the lower portion of this duct becomes differentiated from the upper, so that in the latter the conditions are not such as to favor the formation of a decidua. Abnormally, on account of some developmental anomaly or reversion to an earlier type, the condition of the tubal mucosa is such that a decidua can form, and in such instances we can get an extra-uterine implantation of the ovum. This view has been adopted by a number of observers, but, as is readily seen, it is based upon a theoretical rather than upon a practical basis.

Other observers, among whom may be mentioned Moericke and Fehling, have elaborated Webster's idea in that they claim that the occurrence of extra-uterine pregnancy is a reversion to an earlier type, brought about by poor hygienic conditions. The former authority, basing his conclusions upon a large number of gynecological patients who were under his care in Chili, states that extra-uterine pregnancy is a very rare occurrence among them, whereas at the Clinic in Stuttgart it was observed quite frequently. He attributes this marked difference to the fact that the Chilian women lead an outdoor life, while those of Stuttgart are subjected to very poor hygienic surroundings.

External migration of the ovum, the frequency of which in extra-uterine pregnancy has already been referred to, has led Sippel to put forth a view that is more or less closely allied to that of Webster. Sippel claims that it is necessary for a certain length of time to elapse between fertilization and decidual formation. Thus, when external migration occurs, the ovum is delayed in reaching the genital tract, and then finds in the tube conditions favorable for the formation of a decidua. This view is an interesting one, but is purely theoretical.

IV. *Conditions of the Ovum which may Favor its Arrest in the Tube.*—A few years ago, when the general opinion was that the uterine and tubal epithelium was converted into syncytium, Strassman was of the opinion that as the ovum entered the tube covered by the cells of the membrana granulosa, it could not become attached to the syncytium of the tube until this layer of granulosa cells had disappeared; but if the layer of granulosa was diminished in amount, or if for any reason it was absent, the naked ovum came into direct contact with the syncytially changed tubal mucosa and there became attached, while normally the layer of granulosa prevented this occurrence until the ovum had reached the uterus. This view is no longer tenable, for opinion is now unanimous that the tubal and uterine epithelium does not undergo this change,—*i.e.*, into syncytium,—but that the latter is derived from the fœtal ectoderm.

It is therefore very evident that there is no lack of theories as to the causation of extra-uterine pregnancy. The mechanical theories must be given a certain amount of consideration, but they are open to the objection that while mechanical obstacles are frequently present, the existence of extra-uterine pregnancy is of comparative rarity. On the other hand, recent experimental work on animals—ligation of the tubes and uterine cornua—has failed to cause extra-uterine development of the ovum, after the animal under consideration has been put to the male. Thus these experimenters believe that the supposed extra-uterine pregnancy in the lower animals is really uterine, the mistake being due to confounding the tubes and uterine horns with one another. Tubal diverticula may play an important part, and in some cases undoubtedly exist; but this again cannot hold good for all cases. The same may be said of inflammatory conditions.

We had best close this portion of the subject by quoting from Williams, who summarizes as follows: "The etiology of extra-uterine pregnancy is not a simple matter, and there is no universal cause for all cases. Careful study of the specimen and of the patient's history will give us a satisfactory explanation for its occurrence in the majority of cases, but in a small number we cannot account for the production of the affection, and its cause will remain to us as great a problem as to our predecessors."

CLASSIFICATION.—The fertilized ovum may be arrested at any point between the ovary and uterus. We may thus distinguish between ovarian and tubal pregnancy according as the development occurs in either of these organs. To these two forms some add a third, viz., abdominal pregnancy; but there is considerable doubt as to whether a primary implantation can take place on the peritoneum and thus give rise to this form of pregnancy.

Ovarian Pregnancy.—Ovarian pregnancy was first described early in the seventeenth century, and in the eighteenth was pretty generally recognized. In 1835 Velpeau made the statement that many of the cases described as ovarian pregnancy were open to objections, and he took the rather radical view that none of the cases reported gave to him conclusive evidence as to their ovarian origin. Observers in general agreed with him, and at present there are few who believe in the existence of ovarian pregnancy.

There is evidence, however, that the condition undoubtedly does exist, although very rarely; and, since Spiegelberg reported a case of this nature in 1878, we are in possession of certain criteria by which an ovarian pregnancy can be recognized. Spiegelberg demands that the following conditions be noted before we can make a diagnosis of a given extra-uterine pregnancy being ovarian: (1) The tube on the affected side must be intact. (2) The fœtal sac must occupy the position of the ovary. (3) It must be connected with the uterus by the utero-ovarian ligament. (4) Definite ovarian tissue must be demonstrated in its walls. When judged by these criteria it is clearly seen that many of the cases reported as ovarian pregnancy will be found wanting. Williams, in discussing these points brought out by Spiegelberg, calls attention to the fact that in certain cases of tubal and broad-ligament pregnancy, the ovary may be so flattened out as apparently to occupy a portion of the sac wall, and for this reason he suggests that the fourth condition be so modified as to read: "Definite ovarian tissue must be demonstrated, not at a single point in the sac wall, but at several points a considerable distance from each other."

Williams has carefully reviewed the literature of ovarian pregnancy in the past hundred years and has applied the above criteria to the reported cases. The results of his analysis show that only four cases can be classified as *positive cases*, eleven cases as *highly probable*, and twenty as *fairly probable;* thus clearly demonstrating that, although ovarian pregnancy undoubtedly does exist as a primary condition, it is of the greatest rarity. He also shows that one-half of the positive or probable cases reached full term, indicating that the ovarian tissue can more readily accommodate itself to the increase in size of the growing ovum than can the tube.

In ovarian pregnancy rupture with formation of a secondary abdominal pregnancy can occur, or the case may go to term and the formation of a lithopædion be the result.

Tubal Pregnancy.—When the ovum is arrested in the Fallopian tube and develops there, we have what is known as a tubal pregnancy; this is by far the most frequent variety of extra-uterine pregnancy. According as the arrest of the ovum occurs in the various portions of the tube we can distinguish between ampullar, isthmic, and interstitial pregnancy, the relative frequency being in the order named.

Tait's idea was that the invariable fate of a tubal pregnancy was rupture into the peritoneal cavity, and that this rupture always occurred not later than the twelfth week. Further investigation, however, has proven this view to be an erroneous one, and that many cases terminate at a much earlier period, in what is known as tubal abortion, or that in rare instances the tube may so accommodate itself to the growing ovum that the case may go on to term.

Tubal abortion was thought to be, until quite recently, a pathological curiosity, but in 1887 Werth called attention to the fact that it was not infrequent for the ovum to be extruded through the fimbriated end of the tube into the peritoneal cavity. Attention having been directed to the fact, it is now generally believed that this is the most frequent termination of tubal pregnancy, and in the last three years statistics collected by Martin, Orth, Mandl, Schmidt, and others show that seventy-eight per cent. of the cases end in tubal abortion as against twenty-two per cent. rupturing into the peritoneal cavity. Martin indeed considers that abortion is the general rule and says that rupture occurs only in those cases in which abortion is prevented by closure of the fimbriated end of the tube.

The abortion which occurs in the tube is in a measure analogous to that which takes place in the uterus. The liability to hemorrhage is increased owing to the imperfect development of the decidua. The maternal vessels are opened up by the downgrowth of fœtal ectoderm or trophoblast, and the hemorrhage loosens the embryo from its attachment to the tube wall. If the separation is complete, the ovum is forced through the fimbriated extremity and the abortion can be designated as "complete." On the other hand, if the separation of the ovum is only partial, the hemorrhage continues and the ovum remains in the tube; here the abortion is "incomplete."

It is probable that two factors act in the expulsion of the ovum—viz., the actual contraction of the muscular walls of the tube, and the force from behind furnished by the blood clot. If the abortion is complete, hemorrhage will be profuse; but if the ovum remains in the tube, it may be converted into a "fleshy mole," similar to those observed in uterine abortions.

What has been just gone over has served in the last few years markedly to change the views that were held as to the causation of pelvic hæmatocele and hæmatosalpinx. Opinion is now pretty general that both of these conditions are secondary results of tubal pregnancy. In the first instance the blood flowing through the fimbriated end forms a clot in the neighborhood of the ovary, and in the second the hemorrhage occurs into the tubal lumen and the blood remains there.

Rupture into the Peritoneal Cavity.—As has already been stated, rupture in this manner is not so common as was thought by Tait. When it does occur the pregnancy is usually situated at some distance from the fimbriated end of the tube—either at the isthmus or in the interstitial portion. If it is situated at the isthmus, rupture usually takes place within the first twelve weeks of the pregnancy, and not infrequently during its first month; but if it is situated in the interstitial portion rupture occurs later, for this portion of the tube, being surrounded by uterine muscularis, more readily responds to the influence of pregnancy and allows the ovum to attain a larger size.

Rupture may occur spontaneously or may be brought about by violence; the most frequent form of violence being a rough vaginal examination. The writer recalls a case in charge of a friend in which death from hemorrhage took place twelve hours after a vaginal examination; the diagnosis of extra-uterine pregnancy had not been made. When rupture occurs spontaneously it usually follows some exertion on the part of the patient.

The underlying causes of rupture are twofold, viz., (*a*) overdistention of the tube by the growing ovum and (*b*) perforation of the tube wall by the chorionic villi, which grow down rapidly between the muscle fibres and not infrequently penetrate to the peritoneal coat. The fœtal ectoderm or trophoblast proliferates and causes a certain amount of degeneration of the muscle fibres and connective tissue of the tube wall. If then, as frequently happens, a maternal blood-vessel be opened, the rapid discharge of blood into the tube will cause its overdistention and rupture.

Rupture usually takes place in the neighborhood of the placental site, and hemorrhage and discharge of the ovum will occur either into the peritoneal cavity or between the folds of the broad ligament, depending on the original site of implantation of the placenta.

When rupture occurs into the peritoneal cavity, as a rule the entire ovum is extruded; but if the wound be a small one, there may be profuse hemorrhage without the ovum being discharged. In either case, however, the hemorrhage is profuse and the patient will show marked signs of collapse—or will die before relief can be obtained. In the event of an operation or if a fatal issue should not take place, the result will depend upon the amount of damage which has been done to the ovum.

If the entire ovum escapes into the peritoneal cavity its death is inevitable, and, unless the fœtus is beyond the third month, absorption of the entire product of conception is the rule. The old view that in such a case the placenta may become attached to some neighboring organ and thus form vascular connections is now scarcely tenable; but if the fœtus alone escape from the tube and the placenta remains *in situ*, the effect of the rupture on the pregnancy will vary according to the amount of damage done to the placenta. In those cases in which the greater portion of the placenta remains attached, the fœtus will go on to term as a secondary abdominal pregnancy, and if the original tubal wound has been a small one the placenta will develop in a sac formed by the remains of the tube; but if the rent were large and close to the margins of the placenta, this organ will overgrow its tubal attachments and become adherent to some neighboring organ, viz., uterus, pelvic floor, or intestines. Most observers agree that further growth of the fœtus after escape from the tube is impossible unless it is surrounded by the amnion. There are, however, exceptions to this rule.

Rupture between the folds of the broad ligament takes place in a few cases through that portion of the tube wall which is not covered by peritoneum, and here the tubal contents will pass downward into that space which is situated between the broad ligament and its peritoneal covering. This is considered the most favorable termination of an extra-uterine pregnancy and usually results in the death of the ovum and the formation of a broad-ligament hæmatoma. More rarely the pregnancy may go on to term in this situation; and in such a case it is evident that the placenta, being attached to the unruptured portion of the tube wall, will lie at the superior part of the gestation sac, which condition has given rise to the erroneous idea that the placenta may be attached to some remote organ such as the liver or the diaphragm. In such a case the pregnancy is entirely outside of the peritoneal cavity, and the condition has been spoken of as a broad-ligament or extraperitoneal pregnancy. The gestation sac here has been known to rupture, and a secondary abdominal pregnancy is then the result.

The intimate relation that exists between these pregnancies and the rectum renders them more prone to invasion by intestinal bacteria, and if suppuration should occur the proximity to the bladder explains the discharge of fœtal bones, etc., by way of the urethra—an occurrence which has been noted in such instances.

Williams and others are of the opinion that the frequency of this form of pregnancy has been overestimated, as Williams has observed it only once in about forty cases.

Abdominal Pregnancy.—There is at present little doubt in the minds of most operators that those cases which were thought to be primary abdominal pregnancies have turned out to be only secondary abdominal pregnancies, *i.e.*, secondary to a pre-existing tubal pregnancy, and there is uncertainty as to the possibility of the existence of a pregnancy primarily abdominal. Recent work by Zweifel, Martin, and others, has shown that the fertilized ovum can become implanted upon that thin strip of tubal tissue which extends from the fimbriated extremity of the tube to the ovary, the fimbria ovarica. It is readily seen, however, that such cases are not abdominal but in reality tubal in origin, which, when we bear in mind the fact that small structures covered by ciliated epithelium have been found in the wall of the gestation sac of many cases described as primary abdominal pregnancy, materially weakens the theory as to the possibility of such a form of extra-uterine pregnancy existing. If, for example, an ovum became implanted upon this portion of the tube, the placenta would very rapidly overgrow the very narrow limits of the fimbria ovarica and give one the impression that the pregnancy were primarily abdominal. Williams, in his discussion of this part of the subject, says that, of the cases thus far described, not a single one appears to him to furnish sufficient evidence to justify its being considered primarily abdominal. Nevertheless, in view of the fact that decidual formation has been noted in the sub-peritoneal connective tissue, the possibility of such a thing cannot be denied.

FATE OF THE FŒTUS IN EXTRA-UTERINE PREGNANCY.—Attention has already been called to the fact that when small embryos are extruded into the peritoneal cavity absorption is the rule. This fact is made manifest by the circumstance that one rarely succeeds in finding any trace of the fœtal body in the blood clots which fill the peritoneal cavity after tubal rupture. Absorption frequently takes place within the gestation sac inside of the tube, and when we cut into such a tube it is by no means unusual to find a shapeless mass hanging to the umbilical cord, or even no trace of embryonic body at all, while the cord simply hangs free in the amniotic cavity.

Such a termination, however, is impossible when the fœtus has reached a certain size; it then undergoes one of the following changes: mummification, suppuration, conversion into a lithopædion or into adipocere. In the first of these conditions the fluid portions of the embryo are absorbed and the fœtus becomes converted into a dry, mummified mass, nothing remaining but the bones, covered by a shrivelled skin. When suppuration takes place, as is quite common in cases of broad-ligament pregnancy, the sac first suppurates and the process then extends to the fœtus. The patient, under these circumstances, shows marked signs of sepsis, and, unless the pus is evacuated by operation or by rupture, she will die. Rupture into the bladder or rectum is not an uncommon termination in such instances.

In a small number of cases neither of the above changes takes place, but the fœtus and membranes, by a deposition of lime salts within them, become converted into a calcareous mass or lithopædion. A structure of this character has, in certain instances, been carried by the mother for years, giving no trouble except when it blocks the pelvis and forms an obstacle to normal labor. Küchenmeister has carefully reviewed the literature of this portion of the subject and divides lithopædia into three classes: (1) Calcification limited to the fœtal membranes (lithokelyphos); (2) both fœtus and fœtal membranes partially calcified (lithokelyphopædion); and (3) calcification limited entirely to the fœtus (lithopædion).

The last possible termination—conversion into adipocere—occurs only rarely. Here the fœtus is transformed into a greasy yellow mass; the material is thought to be an ammoniacal soap.

ANATOMICAL CONSIDERATIONS.—It has been the privilege of the writer to examine most of the sections of the specimens of Williams, also to read the manuscript of his as yet unpublished article on extra-uterine pregnancy. In the present section, therefore, I shall quote somewhat fully from his report.

Structure of the Sac Wall in Tubal Pregnancy.—If one is lucky enough to get a specimen of early unruptured tubal pregnancy, one finds that the tube is the seat of a fusiform swelling about 1 or 2 cm. from its uterine end. Sections through a pregnancy at this age show that the sac wall is made up of the muscularis of the tube. The individual muscle cells, however, do not seem to be increased in number but spread apart by œdema. There is marked dilatation of the arteries and veins in this situation, particularly in the neighborhood of the placental site, and there may be some hemorrhage into the lumen of the tube. Later, one will notice marked degenerative changes in the tube wall in the neighborhood of the chorionic villi, so that at this period the sac wall consists of a tissue closely resembling fibrin. The thickness of the tube wall diminishes as the pregnancy advances, and the muscular elements appear to have diminished in number. If the case reach term the sac wall will be found to be composed almost entirely of connective tissue with here and there a muscle fibre, indicating that the muscularis of the tube has not the same tendency to proliferate under the influence of pregnancy as has that of the uterus.

It is not possible to make definite statements as to the part played by the ovary in the formation of the sac wall of an ovarian pregnancy. Maybe if an early specimen could be obtained the entire sac wall would be found to consist of ovarian tissue. The diagnostic value of the presence of ovarian tissue in the sac wall of pregnancies thought to be ovarian has already been referred to, and it is evident that positive statements cannot be made as to the ovarian origin of the pregnancy unless ovarian tissue can be demonstrated in several parts of the sac wall more or less remote from one another.

The condition of the fimbriated end of the tube varies: if tubal abortion has taken place, it is of course patent; while if abortion has not occurred it may or may not be opened. The relation of the lumen of the tube to the pregnancy is also a subject of variation. In certain instances it can be traced into both ends of the fœtal sac, while in others it is apparently completely shut off.

Decidua.—It has long been known that the uterine mucosa under the influence of extra-uterine pregnancy becomes converted into decidua just as it does in uterine pregnancy, and the statement is usually made that its structure is the same under both conditions. However, recently observers such as Williams, Dobbert, and Tussenbroek have pointed out that there exist certain differences in the structure of the two membranes. For example, in uterine pregnancy the spongy layer of the decidua is not so well developed as in extra-uterine pregnancy, and in the former there is a portion of decidua lying under the spongy layer that maintains the appearance of the normal, non-pregnant mucosa. In extra-uterine pregnancy the vessels are markedly enlarged and lie near the surface of the decidua, their rupture accounting for the uterine hemorrhage so frequent in this condition.

Soon after the death of the fœtus the uterine decidua is cast off, either as a whole or in small pieces, a phenomenon said to possess considerable diagnostic importance.

Decidua Vera in the Tube.—The opinion of all of the earlier writers on extra-uterine pregnancy was that a definite decidua vera was developed in the pregnant tubes. In 1891 Bland Sutton denied its existence, and since then there have been many conflicting statements regarding it. If one expects to find a distinct decidual membrane in the pregnant tube analogous to that found in the uterus one will be disappointed, as it does not occur as such; but beyond any possible doubt changes take place in the connective-tissue stroma cells of the tubal folds by which they are converted into cells morphologically similar to the decidual cells in the uterus. This change does not take place throughout the entire length of the tube, but only in discrete patches, and undoubtedly a great part of the tissue which has been described as decidual is in reality fœtal ectoderm. In the specimens of Williams the decidual changes are beautifully shown and the distinct transition from a connective-tissue to a decidual cell can be traced.

The view that a decidua forms in the tube has been materially strengthened by the discovery of analogous changes in the opposite non-pregnant tube, so that at present we cannot deny that a decidua vera is formed, although not to the same extent as in the uterus. The specimens of Williams also show that the columnar epithelium of the tube becomes flattened out just as it does in the uterus.

Decidua Serotina and Reflexa.—From what has just been said, it is evident that the decidua serotina does not reach the same state of development in the tube that it does in the uterus, and undoubtedly that which has so frequently been described as serotina is nothing more than a mass of fœtal ectoderm or "Zellschicht." Careful examination, however, at the point of attachment of the ovum will enable one to differentiate between three varieties of cells, viz., syncytium, "Zellschicht," and true decidual cells.

The same may be said of the reflexa—*i.e.*, while undoubtedly present it never reaches the same stage of development that it does in the uterus. Its existence has been denied by many, but if one examines a carefully prepared intact specimen, one finds a thin layer of tissue separating the ovum from the lumen of the tube. This band of tissue is usually covered on its outer side by flattened tubal epithelium; it contains few if any true typical decidual cells. The cells in this situation can be identified with "Zellschicht" cells, and as pregnancy advances marked degenerative changes in them are seen to occur.

This appearance, particularly in early pregnancy, has led to a number of different explanations: for example, that two tubal folds had grown over the ovum, or that the pregnancy had taken place in an accessory tube lumen. The question has lately been entirely cleared up by the monograph of Peters, in which he describes a young ovum in the uterus (certainly the earliest one as yet described) in which the reflexa has not yet closed over the ovum. Peters is of the opinion that the ovum burrows beneath the epithelium of the endometrium which then closes over it, and there is every reason to believe that the same process occurs on the tube.

Placenta.—Except for the difference in the structure of the tube wall and uterus, and the difference in the formation of the decidua, the structure of the placenta in tubal pregnancy does not differ materially from that in uterine pregnancy. The chorionic villi, not being separated from the muscularis and vessels by a thick layer of serotina, invade more deeply and quickly the tube wall and open up the vessels, thus accounting for the hemorrhage and early tubal abortion. The villi themselves present practically the same appearance in extra- as in intra-uterine pregnancy, their stroma is made up of a loose mucoid connective tissue, and in early cases one can distinguish two layers of epithelium—"Zellschicht" and syncytium. When a villus comes in contact with the serotina its behavior is the same in the tube as in the uterus; viz., there is marked proliferation of the "Zellschicht" at the point of contact, resulting in the formation of a "cell node." If abortion does not occur at an early period, a definite intervillous circulation is established, the intervillous spaces being lined with syncytium just as in uterine pregnancy. The old view that in certain instances the placenta continues to grow after the death of the fœtus is now scarcely tenable.

SYMPTOMS.—The symptoms of an early unruptured extra-uterine pregnancy are by no means characteristic, and frequently one has no idea of the existence of the condition until rupture takes place and the patient is in a state of collapse.

The patient usually considers that she is beginning an ordinary uterine pregnancy, and has the usual subjective symptoms of that condition. There is not uncommonly some pain in one or the other ovarian regions, but usually of so slight significance as not to alarm either the patient or her friends. Menstrual suppression, while not the rule, sometimes occurs. Statistics show that the menses persist in about forty-three per cent. of the cases.

If the fœtus dies at an early period—*i.e.*, before rupture or tubal abortion—there is usually a discharge of blood from the uterus. This may be mistaken for the return of a delayed menstrual period or an early abortion.

In the majority of cases the first indication of anything being wrong is the occurrence of a sharp, lancinating pain in the ovarian region, followed soon by signs of collapse. When collapse occurs it is usually the result of intraperitoneal hemorrhage, either from a rent in the tube wall or from the fimbriated extremity after tubal abortion, and it is readily seen how, unless immediate relief be obtained, the collapse may become deeper and deeper and the individual finally bleed to death into her peritoneal cavity. On the other hand, the hemorrhage may not be of sufficient extent to be fatal, and here the result will be a retro-uterine hæmatocele.

If the hemorrhage is severe the symptoms are those of collapse—weak, rapid pulse, subnormal temperature, pallor, etc.,—while in those cases in which the hemorrhage is slight and is followed by the formation of an hæmatocele, we have a general improvement of the symptoms. The present opinion is that by far the majority of pelvic hæmatoceles are the result of an extra-uterine pregnancy.

Hæmatocele usually is the result of tubal abortion and not of tubal rupture, and according as the hæmatocele occupies the greater part of the pelvis or forms a smaller mass on the region of the fimbriated end of the tube we can differentiate between diffuse and solitary pelvic hæmatoceles. In the former case adhesions of the pelvic viscera are necessary to prevent the escape of the blood into the general peritoneal cavity, but not in the case of the latter, for according to Sänger the solitary hæmatocele is the result of a gradual dripping of blood from the fimbriated end of the tube. The formation of an hæmatocele is almost always a favorable termination for extra-uterine pregnancy, for in this way the acute hemorrhage is checked. However, cases have been reported in which the hemorrhage at the centre of the mass continues, finally causing its rupture into the peritoneal cavity and death. Another unfavorable termination of hæmatocele is suppuration.

Occasionally the patient does not succumb to the first loss of blood, and here, if the placenta is not entirely separated from its attachment to the tube wall, a secondary abdominal pregnancy will result. In such a case the ordinary symptoms of pregnancy will continue, possibly with an abnormal amount of pain.

In a small number of cases rupture may occur between the folds of the broad ligament, and further development go on only to rupture again into the peritoneal cavity; then the fœtus becomes abdominal while the placenta remains between the folds of the broad ligament. Term may be reached in such an instance.

When a patient with a secondary abdominal pregnancy reaches term, what is known as false or spurious labor sets in, during which there are distinct contractions similar to those occurring in the early stages of normal labor. The contractions, however, are not of the gestation sac, for this structure contains so few muscle fibres that its contraction is a matter of impossibility; but the contracting organ is the uterus. False labor continues for several days and during that time the child dies. After fœtal death the placental circulation becomes obliterated; the fœtal sac shrinks and becomes closely applied over the body of the child, which then undergoes one of the changes above mentioned. The abdomen here of course becomes smaller, a symptom which is usually noticed by the patient.

In certain instances the extra-uterine pregnancy may exist at the same time as an intra-uterine one. Parry pointed out the frequency of this occurrence and found that it occurred 22 times in 500 cases. To his 22 cases Williams has recently added others, making the present number of reported cases 49. Parry called the conditions "combined pregnancy." More rarely twin extra-uterine pregnancy has been noted, and in very rare cases both fœtuses were in the same tube.

Repeated tubal pregnancy has been observed and reported in a number of instances. Williams has collected a total of sixty-six such cases in which the diagnosis has been confirmed at operation or autopsy. This phenomenon has been utilized by certain observers to explain points in the etiology of the affection. The anatomical findings, however, have not been uniform, and little information has been gained from this source.

Diagnosis.—The symptoms of an early unruptured extra-uterine pregnancy are so uncertain that they render a diagnosis at this stage almost an impossibility. Tait made the statement that it was impossible to make a diagnosis, and most operators agree with him. In rare cases a diagnosis of the condition is made, but it is almost the rule that after such a diagnosis the operator finds the mass in question to be either an inflamed tube or a small ovarian cyst.

The diagnosis would be based upon the following symptoms: A patient who had been sterile for some time thinks herself pregnant, having the usual subjective symptoms, with possibly an abnormal amount of pain in the ovarian region. If such a patient were the subject of a tubal pregnancy, on examination the uterus would be found to be enlarged and somewhat soft and boggy, and off to one side there would be a small pulsating (?) tumor roughly the size of the supposed pregnancy. But as has already been said, it is common to find after such a diagnosis (?) that the mass is of other than the suspected nature. Taylor has called attention to the fact that the pregnant tube may prolapse into the cul-de-sac of Douglas and give one the impression of a retroflexed pregnant uterus—a statement proven by the fact that several cases have been reported in which rupture of the tube followed an attempt to replace that which was thought to be the fundus.

According to Williams, Veit in Germany in 1883 and Janvrin in this country in 1888 were the first to confirm by abdominal section the diagnosis of unruptured tubal pregnancy. This state of affairs is very rare, the writer never having seen a case in a considerable experience as resident obstetrician in the Johns Hopkins Hospital, and he knows of only one case in the hands of a colleague (Upham, of Columbus, Ohio).

If the fœtus die before rupture of the tube a diagnosis is still very difficult, such cases usually being taken for uterine abortion associated with an inflammatory tubal mass. The source of error is that when the fœtus dies the uterine decidua is cast off in shreds giving the appearance of the discharge of a normally implanted ovum.

Most observers believe that the discharge of a more or less complete decidual cast of the uterine cavity is an infallible sign of extra-uterine pregnancy. The fallacy of this sign is shown, however, by the fact that, relying on this sign alone, some operators (Griffith and Dolan) have opened the abdomen only to find it free from abnormality, or that the supposed extra-uterine pregnancy had been simulated by a small ovarian cyst.

It has been advised that the uterus be curetted for diagnostic purposes, the presence of decidua on the scrapings affording conclusive evidence as to the existence of extra-uterine pregnancy; but as the decidua may have been cast off early in the pregnancy, the discharge being considered by the patient to be a menstrual period, the uncertainty of this procedure is obvious.

A probable diagnosis after death of the fœtus and before rupture can be made in some cases by a careful sifting of the history of the case and by an examination of the patient. For example, she thinks herself pregnant; she has discharged shreds of tissue which may have been decidual. If now an enlarged uterus is found with a small mass on one side corresponding in size to the supposed duration of the pregnancy, a fairly probable diagnosis can be made.

At the occurrence of rupture or of tubal abortion with intraperitoneal hemorrhage, the symptoms are so characteristic that an almost certain diagnosis can be made even without an examination. The patient may or may not have given the above history when suddenly, with a sharp attack of pain in the ovarian region, she goes into a condition of collapse, with weak rapid pulse, pallor, subnormal temperature, etc. Vaginal examination here usually reveals but little, as the patient is too sensitive to allow a thorough exploration. A crepitating sensation may be imparted to the examining finger in the cul-de-sac, due to pressure upon recently clotted blood. With the above symptoms the diagnosis of ruptured tubal pregnancy is practically a certainty, and if not speedily relieved by operation the patient will die. If she recover from the collapse the probabilities are that a tubal abortion has taken place and that the hemorrhage has been checked by the formation of a pelvic hæmatocele.

As tubal rupture may occur very early in pregnancy, even before the patient has thought herself pregnant, one should always regard collapse with signs of intraperitonal hemorrhage as strong probabilities in favor of ruptured extra-uterine pregnancy; and in such a case only by acting promptly can the life of the patient be saved.

If, as is often the case, she is not seen until after primary rupture, examination will reveal a large tumor filling the posterior portion of the pelvis, and an exploratory puncture through the posterior vaginal fornix will render the diagnosis certain.

In cases in which the fœtus has survived the damage done at the time of primary rupture and has continued to develop in the abdominal cavity or in a gestation sac, the diagnosis is not usually made, because our attention is not directed to the fact of early rupture, and it is not until false labor sets in that our suspicions arise as to the child's not being in the uterine cavity. If careful examination be made, however, the condition should offer little difficulty; the child is found to be more easily palpable than normal, its movements give the mother a certain amount of pain, and by bimanual examination the uterus is found to be practically normal in size. If an hæmatocele has formed between the folds of the broad ligament, the mass will lie largely in the small pelvis and the uterus will be pushed over to one side.

When an extra- and an intra-uterine pregnancy occur together and have reached term, the diagnosis of twins has usually been made, and it is not until the cause of delay in the birth of the second child is investigated that its extra-uterine existence is noted.

TREATMENT.—*Before Rupture.*—When an extra-uterine pregnancy is diagnosed before rupture, it must be regarded as a malignant growth and removed by laparotomy as soon as possible. This procedure cannot be too urgently advised, for until it is removed the patient is in imminent danger of a fatal rupture. All methods which have as their end the destruction of the fœtus, such as electricity or the injection of medicinal substances, are to be strongly condemned; for, as we know, even the death of the child does not preclude the possibility of rupture of the tube. However, from what has already been said, it is apparent that such a line of treatment will rarely be thought of owing to the uncertainty of diagnosis at this time.

After Rupture.—Although laparotomy was advised some years ago for the removal of a ruptured tube, operators were not willing to accept this plan of treatment until Tait demonstrated the ease with which the diseased tube could be removed and hemorrhage checked. This method is now almost universally employed, and all of us can recall numerous instances in which life has been saved by it.

The diagnosis of ruptured tube and intraperitoneal hemorrhage once having been made by the very characteristic symptoms already discussed, the abdomen must immediately be opened (unless the degree of collapse is so great that the patient is moribund when first seen). Then immediately afterward long clamps are to be passed down into the pelvis and applied on both sides of the tubal mass. This will at once check all hemorrhage, and the injured tube can be excised without unnecessary haste. If the peritoneal cavity is filled with clotted blood which obscures the field of operation, the clamps must be applied by the sense of touch alone.

An excellent method of counteracting the effect of the loss of blood is by the infusion of normal salt solution. This can be done during the operation and the infusion allowed to run into the submammary subcutaneous tissue or injected directly into the circulation.

In tubal abortion some operators have made the attempt to save the affected tube. The advisability of such an attempt appears to be of doubtful nature, as it has not been proven that the tube once affected ever regains its functional activity.

Operation through the vagina has lately been advised and even now has many adherents. As it has many obvious disadvantages, it is mentioned here only to be condemned. Among the disadvantages may be mentioned the small field of operation in the vaginal method as compared to the large one in the abdominal, and the frequent necessity of having to open the abdomen to arrest hemorrhage which has been started in the vaginal operation.

Hæmatocele.—It has been shown that the majority of cases of pelvic hæmatocele undergo spontaneous cure and rarely require operation. Thorn reports 157 cases, in only 6 of which was operation thought necessary, the rest having been treated by careful watching and rest in bed. The total mortality here was only six-tenths of one per cent. Fehling has reported 91 cases, treated in a similar manner, without a single death. A disadvantage of the method, however, is that it is extremely slow and the patients have to remain many weeks in bed.

On the other hand, there are certain conditions which render operation imperative in cases of hæmatocele: such indications as rapid increase in the size of the tumor, signs of suppuration, or pressure on important organs. When such conditions are present the hæmatocele is best attacked by way of the vagina. An incision is made through the posterior vaginal wall, the clot is evacuated, and the cavity is at once packed with sterile gauze. This usually gives most excellent results, but all operators agree that it is frequently necessary to open the abdomen in order to check hemorrhage that cannot be controlled by the pack; therefore one should always have the abdomen prepared for a laparotomy before making the vaginal incision.

Treatment during the Latter Months of Pregnancy.—Occasionally in the latter half of pregnancy we shall find the fœtus enclosed in a large tubal or ovarian sac; more commonly, however, the fœtus has escaped through the rent in the tube wall and we have to deal with a secondary abdominal pregnancy in which the placenta is attached to the pelvic floor while the fœtus lies free. In such cases, as there is always danger of a secondary rupture, prompt laparotomy is indicated. If the child is within a few weeks of viability some have advised a waiting policy, thus giving the child a chance that it would not have were immediate operation done. If such a course be decided upon the dangers to the mother should always be explained to the family.

As to the best method of operating in such cases, unquestionably the ideal procedure is to open the abdomen and remove the entire gestation sac; but frequently, on account of adhesions to neighboring organs, such a course is inadvisable, and here the sac should be incised, care being taken to avoid wounding the placenta if possible. Then the child should be removed and the edges of the sac should be stitched to the margins of the abdominal wound, the cavity being packed with gauze and the placenta allowed to come away piecemeal. This entails a longer convalescence, but on the whole is better than endangering the life of the patient by attempting to remove an adherent placenta. In certain cases this plan cannot be carried out, and then the entire sac must be removed no matter how serious the procedure may seem.

When the fœtus dies the danger to the mother materially diminishes, for, when the fœtal circulation ceases, the hemorrhage from the placental site is not so much to be feared. If a diagnosis of the death of the child be made, operation should be deferred for a short time in order to favor closure of the maternal blood spaces and separation of the placenta; it being understood, however, that immediate operation may be necessary at any time.

George W. Dobbin.

EXUDATION, PATHOLOGICAL.—One of the chief phenomena of inflammation is the passage of a portion of the fluid and cellular constituents of the blood from the blood-vessels into the tissue spaces or out upon one of the free surfaces of the body. This process is known as exudation, and the fluid and cells which have left the vessels as an exudate. *Exudation* is distinguished from *transudation* in that it is always a part of an inflammatory process, while the latter term is commonly restricted in its application to an increase in the formation of lymph not due to inflammation, but dependent upon changes in blood pressure, alterations in the blood, or in the vessel wall which favor an increased lymph production (œdema). *Exudates* differ from *transudates* in their higher albumen content, higher specific gravity (1.016–1.025), and their greater richness in cellular elements. Transudates have a low specific gravity (1.006–1.008, rarely reaching 1.012), contain but few cells, and differ but little in their composition from that of normal lymph, their albumen content being very slight, sometimes lower and sometimes slightly higher than that of lymph. Exudates are usually turbid from the large number of leucocytes contained in them, while transudates are usually clear or but slightly cloudy.

The source of both the fluid and the cellular constituents of exudates is the blood, and the escape of these from the vessels is due to some alteration in the vascular walls which forms an essential part of the inflammatory process. Evidences of this alteration are seen in the dilatation of the vessels, the increased resistance offered to the blood current with consequent slowing of the circulation, the increased adhesion of the cellular elements of the blood to the vessel wall, and, most important of all, the increased permeability of the walls. The composition of the exudate is therefore dependent upon the degree of pathological alteration as well as upon the peculiar property of the affected vessel. The greater the injury the greater the exudate and the amount of albumen and cellular elements contained in it. Moreover, since the properties of the blood-vessel walls differ in different regions of the body, the character of inflammatory exudates in different parts will also vary; thus the albumen content of pericardial and pleural exudates is higher as a rule than that of peritoneal. Exudates differ further in the proportionate amounts of the various blood elements contained in them. In one case the exudate may be almost entirely fluid with a very small number of cells (serous exudate); in another, the leucocytes may be so numerous as to give the exudate a more or less thick, creamy appearance (purulent exudate); or the escaped fluid may contain large amounts of fibrinogen and fibrin ferment (fibrinous exudate). Further, many red blood cells may escape by rhexis or diapedesis (hemorrhagic exudate), or large numbers of blood plates may be present in the exudate. Combined characteristics exist, so some exudates may be properly styled sero-fibrinous, sero-purulent, fibrino-purulent, etc. Besides the blood constituents inflammatory exudates also contain tissue débris, fluids arising from cellular liquefaction and degeneration, etc. The high proportion of albumen in many exudates is due partly to proteids derived from cellular destruction. In exudates there may be contained also poisons arising from tissue destruction or, in infective inflammations, from the growth of micro-organisms; the bacteria themselves, and cells arising from the proliferation of fixed cells of the tissue, may likewise be present.

The various problems regarding the manner of escape of the exudate from the blood-vessels have offered abundant scope for investigation and speculation, and a survey of the various theories evolved to solve these problems forms one of the most interesting historical chapters in the development of pathology. The existence of pathological exudates was very early recognized. Rokitansky believed that they arose from an increased permeability of the wall of the vessels due to thinning from overdistention. Vogel, Paget, and others explained their formation as being due to an increased attraction between the tissues and the elements of the blood. Virchow distinguished two kinds of exudates: one the result of mechanical pressure in the vessels, pressed-out blood serum; the second as nutritive, the result of an increased attraction between the tissues and blood constituents. The cellular portion of the exudate he believed to originate from a proliferation of the tissue cells in the inflamed area.

Dutrochet in 1842 and Waller in 1846 first observed the migration of leucocytes from the vessels, but these observations were forgotten until Cohnheim in 1867 rediscovered the phenomenon. This observer affirmed that the passage of leucocytes from the vessels formed the essential feature of inflammatory exudation; that the cells in inflamed areas did not arise from the tissue cells; and he explained the origin of the fluid portion of the exudate as due to a molecular change in the vessel wall. This view was opposed by many, notably Stricker, who held that the greater part of the cells in inflammatory exudates were not leucocytes but new cells arising out of the inflamed tissue, pus cells therefore taking their origin from connective-tissue cells.

Heitzmann believed also that the cells of the exudate were not leucocytes, but were embryonic cells arising from the softened or dissolved intercellular substance. More recently Grawitz has taken a similar position, in that he declares the cells of the exudate to arise from so-called "slumbering cells" in the intercellular substance of connective tissue which under normal conditions are not visible. The views of Stricker, Heitzmann, and Grawitz find little acceptance at the present time, the almost universally accepted opinion being that the chief part of the cells of inflammatory exudates at least arises from the blood.

Heidenhain explains the formation of lymph as a process of secretion on the part of the cells of the vessel walls and not as a pure filtration process. Pathological stimulation of this process or alterations in the vascular walls will change the amount and character of this secretion. A portion of the fluid of exudates at least must be regarded as being of the nature of a pathological cell secretion. According to Arnold, Thoma, and Engelmann the formation of the exudate is due chiefly to changes in the lines of cement substance lying between the endothelial cells of the vessel wall. Through distention of the vessel the cement substance may be so thinned as to form small openings through which both fluid and cellular elements escape. Other writers hold that the escape of the leucocytes is not due to alterations in the vascular walls but to chemotactic influences acting from outside of the vessels and causing the cells to pass through the wall.

At the present time the exact nature of the process by which exudates are formed cannot be said to be definitely fixed. The most commonly accepted view is that the chief part of the fluid and cellular elements comes from the blood, and that both pathological secretion and alterations in the wall, as well as chemotaxis, play parts in the formation of the exudate. The escape of the leucocytes is considered an active process brought about by means of their amœboid power in response to chemotactic stimuli. In the very earliest stages of the inflammatory process the cells of the exudate are wholly leucocytes; later, tissue proliferation begins and a part of the cells of the exudate may thus be derived from tissue cells.

Recently much attention has been given to the closer study of the leucocytes found in exudates. Lubarsch divides the cells of inflammatory exudates into hæmotogenous wandering cells and histogenic wandering cells, in the former case descendants of immigrated cells, in the latter arising from fixed connective-tissue cells. The relative proportion of these cells varies in different forms of inflammation, and in different stages of the same form; but the immigration of leucocytes forms the most prominent feature of the majority of inflammations. Until recently it was affirmed that the migrating leucocytes were chiefly polynuclear forms and that these only possessed the power of active movement. Welch, Councilman, and others have shown that lymphoid cells may also migrate, a fact which was formerly denied. The so-called plasma cell also appears to play an important rôle in many exudates, particularly those of chronic inflammation. This cell is now believed by the majority of writers to be of hæmatogenous origin, most probably a form of lymphocyte. It is characterized by a protoplasm staining blue with methylene blue, an eccentrically placed nucleus, a perinuclear clear space, and a nucleus possessing a number of coarse particles of chromatin arranged on the inner surface of the nuclear membrane. Plasma cells occur in large numbers in the cellular exudate of chronic inflammations, particularly, as Councilman has shown, in the interstitial nephritis of scarlatina. This observer believes that they are lymphocytes which migrate as such or as plasma cells from the blood, and multiply outside of the vessels in response to chemotactic stimuli. It would appear, then, that there are selective chemotactic stimuli; part influencing the migration of lymphoid and plasma cells, part the polynuclears or other varieties of leucocytes. Some exudates contain large numbers of eosinophiles and mast cells, but the significance of such occurrence is not yet known.

Wieniarski confirms the assertion of Korczynski and Wernicki that lymphocytes predominate in exudates not due to malignant disease or showing a tendency to become purulent. When neutrophile polynuclears predominate the exudate is caused either by malignant disease or by pus-forming agents. According to these observers the presence of eosinophile cells and red blood cells in exudates is without significance. In pleural and peritoneal transudates the cells are almost exclusively lymphocytes; in pleural exudates of serous nature they are also lymphocytes; the predominance of polynuclears always indicating a purulent process in case no malignant disease is present. In one case in which but few leucocytes were present in the exudate, but these all polynuclears, a purulent exudate developed later; in another case in which 6,230 lymphocytes were present in a cubic millimetre of the exudate the inflammation did not become purulent in character. The same facts apply also to peritoneal exudates. In serous pleural exudates the number of lymphocytes varies from 270 to 9,270 per cubic millimetre, in transudates from 60 to 300. In peritoneal transudates even smaller numbers of lymphocytes are usually present. During the absorption of exudates the number of leucocytes increases; during fibrinous exudation they are found in smaller numbers. Much work yet remains to be done along this line, as many important problems regarding the fate of the migrated cells have yet to be settled.

The fluid and cellular exudates from the vessels collect first around these, but soon spread into the lymph spaces of the neighboring tissues forming an infiltration. If the exudate is very abundant the neighboring healthy tissue may be infiltrated to such an extent that it may be damaged and the inflammatory process spread. The tissue elements may absorb a portion of the exudate, and become swollen or vacuolated; or all of the tissues may become dissolved in the exudate. If fibrinogen and fibrin ferment are present, coagulation may take place either before or after liquefaction of the affected tissue takes place. Open spaces in the tissues, such as the lung alveoli, may become filled with the exudate; if the inflammation involves a body surface the exudate may either collect in one of the body cavities or be discharged from a free surface.

The first pathological changes which find expression in the formation of a pathological exudate are vascular phenomena which are due either to irritation or paralysis of the vaso-motor system, or to a direct action upon the walls of the vessels themselves, the result in either case being a dilatation of the vessel. This change may, however, take place without the production of an exudate, but it always precedes exudate formation when the latter occurs. Following the dilatation of the vessel there is a slowing of the blood stream and with this a marginal collection of the leucocytes along the vessel wall; and finally diapedesis of the cellular elements takes place simultaneously with the passing out of the fluid portion of the exudate. The passage of the leucocytes is an active process accomplished by means of amœboid movement, and is only an increased degree of a process which takes place to a limited extent normally (wandering cells). The cause of the increased diapedesis of leucocytes in inflammation is probably partly chemotaxis and partly changes in the vessel wall. According to Arnold and Thoma the leucocytes pass through the endothelial cement substance which is stretched and thinned by the distention of the vessel. The leucocyte first sends a process through the thinned portion of the wall, and through the opening thus made the remainder of the cell body slips after. Through the opening formed in this manner the red blood cells and fluid elements of the blood may also pass.

The passage of a serous exudate into a body cavity, as the pleural or peritoneal, is spoken of as a serous effusion. Serous exudates on mucous membranes are styled catarrhs; localized collections of fluid beneath the horny layer of the skin are blisters, vesicles, bullæ, or blebs. The serous infiltration of tissue spaces is an inflammatory œdema. On mucous surfaces serous exudates may contain a large percentage of mucin derived from mucous degeneration of the epithelium (mucous catarrh); or a loosening of the epithelium into the exudate may occur (desquamative catarrh). If flakes of fibrin are formed in the exudate it may be styled sero-fibrinous; if the number of leucocytes is so great as to make the fluid slightly turbid, sero-purulent.

Fibrinous exudates occur either upon mucous or serous surfaces, into the lung alveoli, or into tissue spaces. On mucous membranes they form whitish or grayish croupous or diphtheritic membranes which are either loosely or firmly adherent to the tissues beneath. These membranes are made up chiefly of granular or fibro-granular fibrin, occasionally in coarse bands or hyaline masses. In fibrinous effusions large masses of stringy fibrin may float in the exudate, while the serous surface may be covered with a thick layer of stringy fibrin, or in mild cases only small strings or flakes may be scattered over the surface. In the lung the alveolar spaces may be completely filled with a network of fine fibrin fibrillæ enclosing leucocytes, red blood cells, and desquamated epithelial cells in its meshes. In the kidneys fibrillar or hyaline fibrin may be found in the tubules. In the follicles of the spleen and lymph glands the spaces between the cells may be filled with a fibrinous exudate. The intercellular spaces in tubercles are also commonly filled with an exudate of fibrin. According to Neumann the fibrinous material found in certain inflammations of serous membranes is not an exudate, but the result of a "fibrinoid degeneration" of the superficial connective tissue of the membrane. This theory is not supported by the actual findings, and has not been generally accepted.

If the inflammatory exudate contains a large number of leucocytes, but not in a sufficient number to cover up the structure of the tissue, it is spoken of as a small-celled infiltration. When the leucocytes in the exudate are so numerous as to give it a white or creamy appearance it is called pus; such an exudate on mucous membranes is a purulent catarrh; in the body cavities a purulent effusion or empyema. Purulent vesicles are styled pustules; deep-seated purulent exudates, abscesses. Seropurulent exudates may infiltrate the tissues (purulent œdema). Fibrin is a very frequent accompaniment of purulent exudates (fibrino-purulent exudate); and the inflammations of serous membranes usually produce exudates of this kind. Usually with an increase of pus formation the amount of fibrin decreases and the fibrin masses present in the exudate begin to dissolve. Fibrin coagula infiltrated with leucocytes become white and friable. The presence of large numbers of red blood cells (hemorrhagic exudate) and blood plates is found usually in association with fibrinous exudation, but they may also be present in serous inflammations.

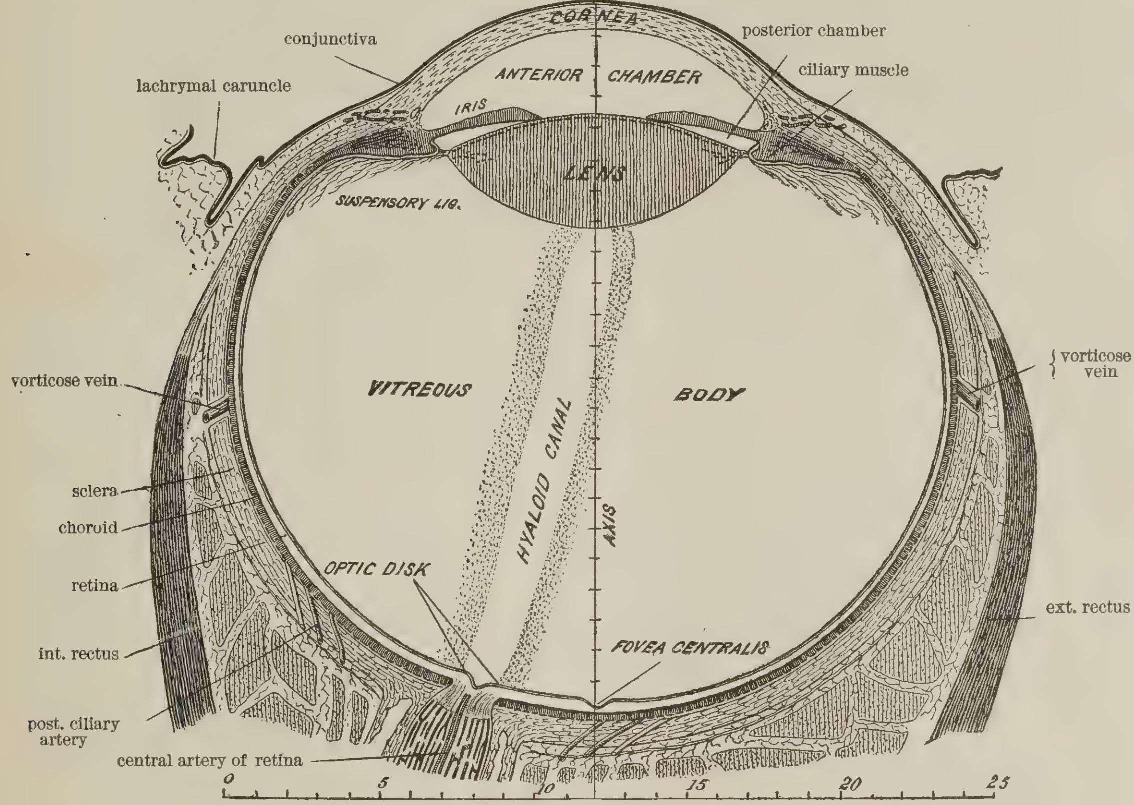
The exciting causes of pathological exudation are those of inflammations in general. Serous, sero-fibrinous, and fibrinous exudates may be caused by thermal and chemical means; but are most frequently due to infection with the Diplococcus pneumoniæ, Bacillus diphtheriæ, and the Streptococcus pyogenes. Purulent exudates may also be caused by chemical action, but are most frequently the result of infection by the Streptococcus pyogenes, the staphylococci, gonococcus, etc. After the causes which have produced them cease to operate exudates are discharged from the body, absorbed, organized, or under certain conditions encapsulated and calcified. In the processes of repair and organization it is possible that the exudate may serve as a source of nutriment for the new-formed tissue cells.

The significance of pathological exudations is practically that of inflammation in general. The old view, and the one still commonly accepted by clinicians, is that they are essentially harmful. From the pathological side, however, inflammation must be regarded as a reaction on the part of the body to local injuries, having for its purpose protection and repair. Though both protective and reparative measures may be imperfectly carried out and even many times in themselves cause further damage, it must be granted that inflammation is essentially an attempt at self-preservation. In this attempt the constituents of the exudate, both cellular and fluid, play the chief part. The leucocytes of the exudate act as phagocytes and as sources of bactericidal and antitoxic substances, or may even furnish nutriment to formative tissue. The fluids of the exudate likewise possess important germicidal and antitoxic powers; they serve further as diluting and irrigating agents; and may also carry nutriment to the newly forming cells. Even fibrinous exudates may serve a beneficial purpose in limiting the action of bacteria. Masses of leucocytes may also form mechanical barriers to the spread of germ growth.

In the exudate we therefore find the means of counteracting or destroying harmful agents, neutralizing their poisons, protecting the organism, and aiding in healing. But in the attempt to fulfil these functions exudates may in themselves create new conditions that may damage the body. The pressure upon the brain of meningeal exudates, the disturbance of respiration and heart's action by pleural and pericardial effusions, the closure of the glottis from inflammatory infiltration, etc., are examples of the imperfect adaptation of the process, which though in the main intended to be beneficial may often overreach its aim.

(See also *Inflammation.*) *Aldred Scott Warthin.*

EYE.—General Arrangement.—The eyeball (see Fig. 1952) is a spheroidal expansion attached to the end of the optic nerve, optically equivalent to a camera obscura and filled with fluid or semifluid contents. It has three concentric envelopes or coats: an outer one, protective in character, formed of fibrous tissue, called the *sclera* behind, where it is white and opaque, and the *cornea* in front, where it is clear and transparent; a middle one, nutritive in character, composed of vascular tissue intermingled with pigment, called the *choroid* behind, in front assisting to form the *iris* or diaphragm which regulates the admission of light through a central aperture, the *pupil;* an inner one, percipient in character, formed of nervous elements and called the *retina.*



Scale of millimetres.

Fig. 1952.—Diagram of Horizontal Section of Eyeball Drawn to an Accurate Scale. (Flemming.)

The rays of light that pass through the pupil are focussed dioptrically by the refractive action of a clear, lenticular body, the *crystalline lens,* which is set behind the iris and divides the cavity of the eyeball into two compartments or chambers: the *aqueous chamber,* situated in front and containing a watery fluid called the *aqueous humor,* and the *vitreous chamber* behind, containing the semifluid *vitreous humor* or *body.* The aqueous chamber is subdivided by the iris; the space in front of that curtain being known as the *anterior chamber,* that between it and the lens as the *posterior chamber.*

In describing the eye terms applicable to a spheroid are used (see Figs. 1953 and 1954). The antero-posterior diameter is termed the *axis,* the ends of that diameter the *poles.* The *equator* is a line on the surface equidistant from these poles; circles and directions parallel to it are

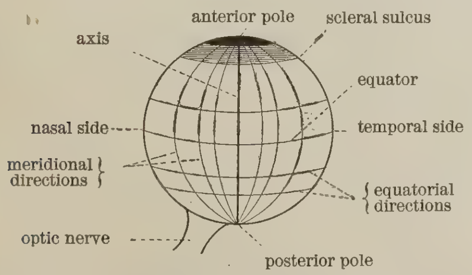


Fig. 1953.—Diagram of Right Eye, as Seen from Above, to Illustrate Terms of Orientation.

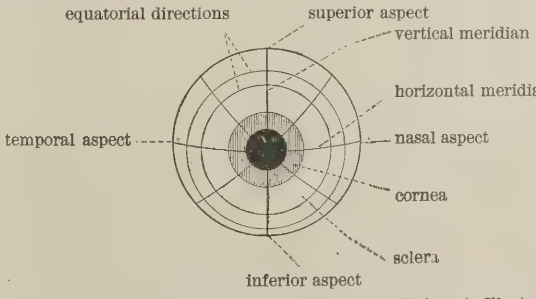


Fig. 1954.—Diagram of Right Eye, as Seen from Before, to Illustrate Terms of Orientation.

termed *equatorial.* Circles drawn from pole to pole are termed *meridians,* directions along these are *meridional.* Any half of the ocular globe is called a *hemisphere,* any fourth a *quadrant.* The lateral aspects of the globe are distinguished as *temporal* and *nasal.*

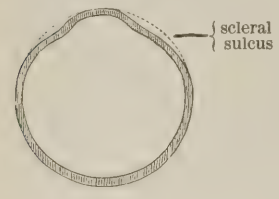


FIG. 1955.—The Eyeball Compared with a Sphere.

The eyeball is not a perfect sphere. Its antero-posterior diameter averages 24.2 mm., its transverse diameter 23.6 mm., and its vertical diameter 23.2 mm. The radius of curvature of the cornea is considerably less than that of the sclera and a slight groove, the *scleral sulcus,* separates the two (see Fig. 1955). Individual variations may lead to visual defects. An examination of the annexed figures (Figs. 1956, 1957, and 1958) will show that a lengthening of the axis of the ball may cause the rays from distant objects to focus in front of the retina, while a shortening of that axis may focus them behind it. The average weight of the eyeball is about 7 gm., its specific gravity about 1.077. At birth its weight as compared with the rest of the body is as 1 : 419; at maturity it is as 1 : 4,832.

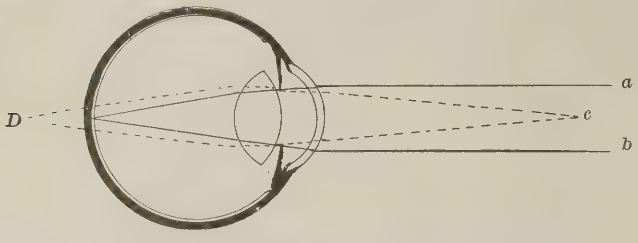


FIG. 1956.—An Emmetropic or Normal Eye. Parallel rays, *a b,* are focussed upon the retina; while divergent rays, as those proceeding from the point *c,* come to a focus *behind* the retina, as at *D.*

RELATIONS.—The eye is placed just within the margin of the pyramidal cavity of the orbit, 16 to 18 mm. from the optic foramen (Figs. 1959 and 1960), usually a little nearer to the upper margin and to the temporal side, though equidistant from the upper and lower walls at the equator (Fig. 1961). It fills about one-fifth of the cavity, the remainder being occupied by the ocular vessels, nerves and muscles, the lachrymal gland and the bulbar fascia, loose orbital fat lying in the interstices. The edge of the orbit retreats somewhat on the temporal side so that the eyeball is there somewhat more accessible for operation.

In front the eye is protected by two movable folds of integument, the eyelids, or *palpebræ,* which, when open (Fig. 1962) form an aperture known as the *rictus palpebrarum* or palpebral opening that exposes nearly the whole of the cornea and a considerable portion of the sclera. About 30 mm. in length and 12 to 15 mm. high, it is curved above and below, uniting internally and externally at the *angles* or *canthi* of the eye. The external angle is sharp, the internal rounded, forming a slight recess known as the *lachrymal bay.* It is here that are found passages for the removal of the lachrymal fluid (Fig. 1963). Two small openings, the *puncta lachrymalia,* lead into the short lachrymal ducts which discharge through the nasal duct into the inferior meatus of the nose. With horizontally directed vision the upper lid impinges slightly upon the cornea, the lower falls near its inferior edge; when looking upward a strip of sclera is visible below. The axis of the palpebral opening is slightly higher at the outer angle, but when the eyes are closed (Fig. 1964) the outer angle descends.

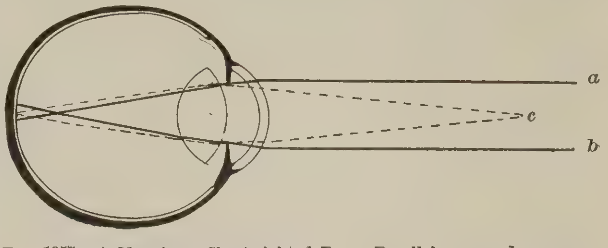


FIG. 1957.—A Myopic or Short-sighted Eye. Parallel rays, *a b,* converge before reaching the retina. Rays must be *divergent* in order to focus there.

The lids are lined by a thin epithelial membrane, the *conjunctiva,* which extends from them over the anterior surface of the ball (Fig. 1965). The

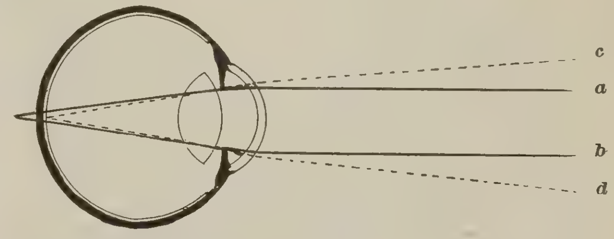


FIG. 1958.—A Hypermetropic or Far-sighted Eye. Parallel rays converge *behind* the retina. Rays must be *convergent* in order to focus there.

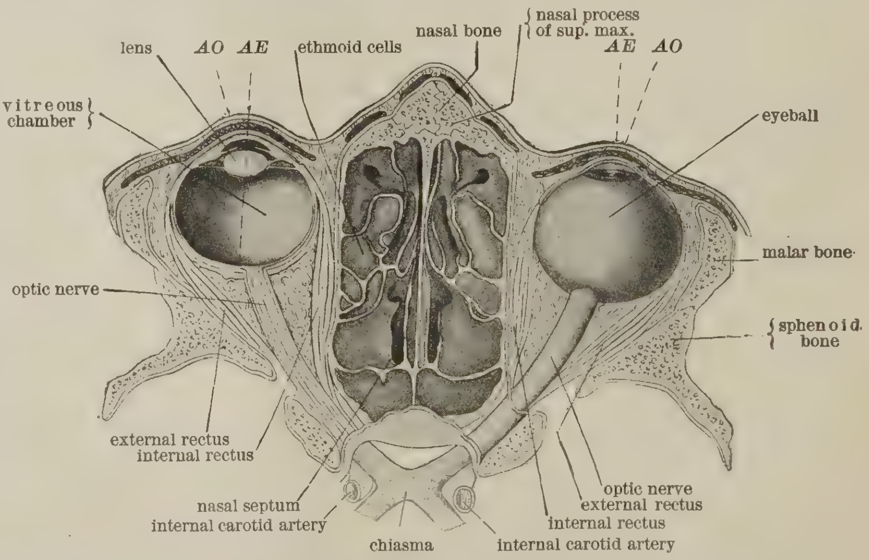


FIG. 1959.—The Eyes and Optic Nerves Seen from Above after Removal of the Roof of the Orbit. *AO,* Axis of Orbit; *AE,* axis of eye.

place of reflection is known as the *fornix* of the conjunctiva and is situated 13 mm. from the upper lid, 9 mm. from the lower one when the eyes are open. Its distance from the cornea is 10 mm. above, 8 mm. below, 14 mm. at the outer angle, and 7 mm. at the inner angle (Testut).

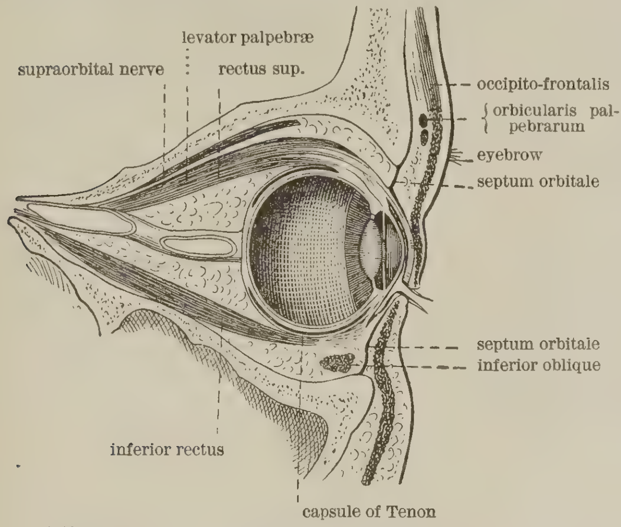


FIG. 1960.—Sagittal Section of the Visual Apparatus Through the Summit of the Cornea and the Optic Foramen. (Merkel.)

Within the orbit a thin aponeurotic sheet, the *bulbar fascia* or capsule of Tenon, separates the eyeball from the orbital fat (Fig. 1966). This invests the posterior part of the ball with two layers, one closely adherent to the sclera and sometimes called the *episclera*, the other reflected over the orbital contents. The two layers are united by fine trabeculæ, and there is between them a loose lacunar interval, the *periscleral space*, that communicates with the perineural space of the optic nerve. Processes from the bulbar fascia invest the structures that pass to the eyeball. Those that extend upon the ocular muscles are of considerable surgical importance. Extensions also pass to the fornix of the conjunctiva, to the eyelids, and to the edges of the orbit. As the latter assists to retain the contents of that cavity, it is known as the *orbital septum*.

DEVELOPMENT.—The percipient portion of the eye is, like the essential part of other organs of sense, derived, either directly or indirectly, from the ectoderm. In its simplest form, as seen in invertebrates, it consists merely of tegumentary cells, forming eye spots or retinas, surrounded by pigment and communicating by filamentous processes with nervous ganglia. Often, by a thickening of the epidermis, one or more lenses are developed in connection with these.

In vertebrates the ectodermal integument becomes infolded to form the central nervous system, and the development of the eye is more complicated. In Amphioxus there appears, toward the close of the embryonic period, on the swollen anterior end of the simple tube that forms its central nervous system, a pigmented spot that is believed to represent an eye. To this spot rays of light pass through the pellucid jelly that covers the animal externally, and, arrested by the pigment, excite directly the cells of the neural tube and apparently impart an obscure sensation of vision. In this primitive form, therefore, vision appears to be a direct function of a specialized portion of the central nervous system.

An examination of the visual organs of higher vertebrates, including man, shows that here too the essential element was primitively a portion of the central nervous system which, extending peripherally, became separated and associated with other elements to form a complicated apparatus. The retina may be regarded as a specialized portion of the cortex of the brain, the optic nerve as a fibre tract, the lens as an epithelial invagination, the cornea, sclera, choroid, and contents of the eyeball as connective-tissue derivatives.

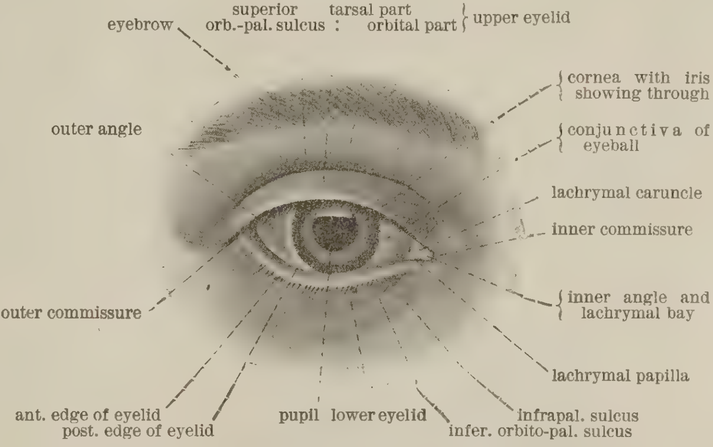


FIG. 1962.—The Eye as Seen with Lids Open. (Toldt.)

In the human embryo of three weeks (corresponding to the chick of two or three days) the central nervous system is also tubular, being formed by the approximation and gradual concrescence of the edges of a groove. The area that is to form the retina lies at first along the outer edges of the groove, in the region known as the neural crest, from which also originate the cells for the sensory nerves. The retinal cells differ from the latter in that, as the edges of the groove fold over to form the tube, they are gradually drawn in until they lie along the sides of the cavity (Fig. 1967, A, B, C, D).

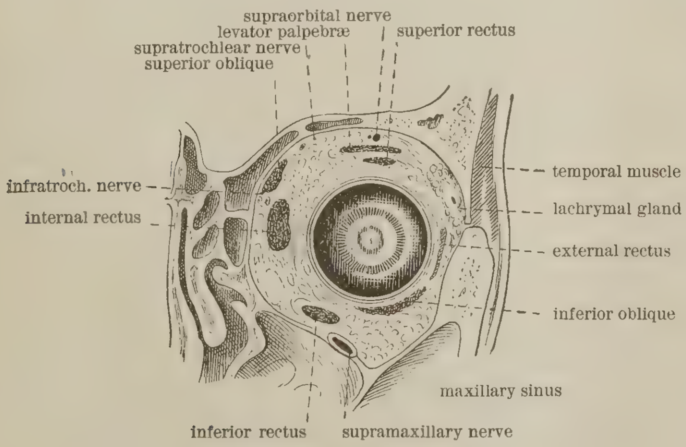


FIG. 1961.—Frontal Section of the Eyeball in the Orbit. (Merkel.)

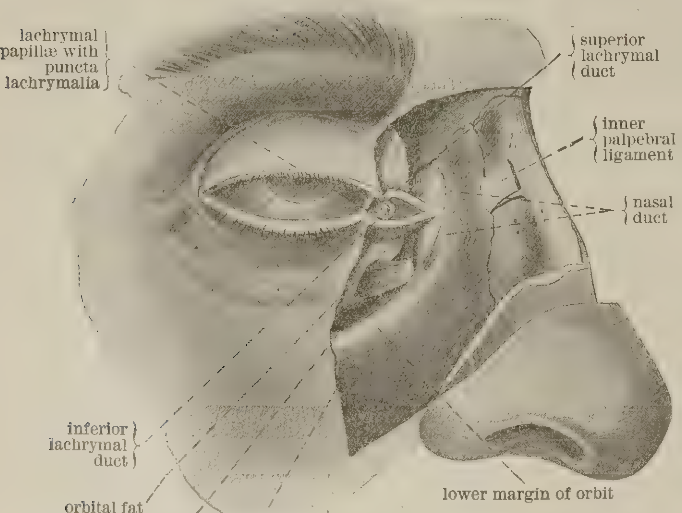


Fig. 1963.—The Lachrymal Passages.

This peculiar displacement of the cells of the retinal area is made possible by delay in the concrescence of the edges of the groove. If this occurs prematurely the fœtus develops but a single orbital cavity, a teratological phenomenon known as *cyclopia*, which differs according to the stage at which union takes place. If early, the two retinas may be fused together to form a single eye; somewhat later, the two are imperfectly united; still later, two eyes exist in a single median orbit.

At the period we are considering the neural tube shows at its cephalic end three bulbar enlargements, the primary cerebral vesicles. It is from the anterior of these, the forebrain, that are formed the parts immediately concerned with vision: the retinal areas, the optic nerves, the corpora geniculata, and the optic thalami. The forebrain now widens out laterally, forming two hollow protrusions, whose bulbar extremities, containing the retinal areas, are called the primary ocular vesicles, the constricted pedicles, from which the optic nerves are formed, being known as the optic stalks. The cavity of each still communicates freely with that of the forebrain (Figs. 1968, 1969).

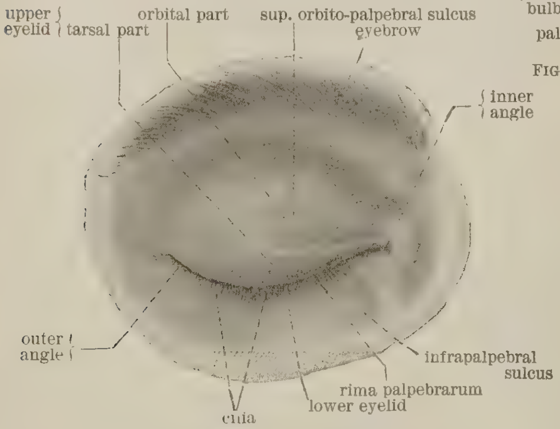


Fig. 1964.—Eyelids of Right Eye when Closed.

The ocular vesicles in their outward growth soon reach the epithelium or ectoderm of the side of the head which, at the place of contact, becomes thickened and cupped. This cupping or invagination continues until another vesicular structure is formed, the lenticular vesicle, from which develops the crystalline lens. The intrusion of the lens upon the growing end of the ocular vesicle causes the latter to assume a shape like that of a thin hollow rubber ball with a marble somewhat smaller in size pressed against its surface (Fig. 1970). Because of this change of form it is henceforth called the optic cup (secondary ocular vesicle). The successive changes are shown diagrammatically in Figs. 1971 to 1975. The edge of the cup is the future margin of the pupil; its walls are double, the inner or retinal layer being much thicker than the outer one in which pigment is deposited; they are at this stage deficient below where growth is less rapid and a fissure is thus formed, known as the choroidal cleft, through which

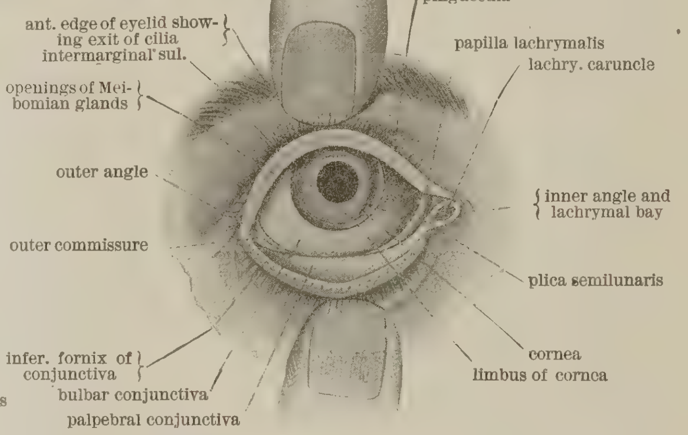


Fig. 1965.—Widely Opened Eye of an Elderly Person; Lower Lid Everted.

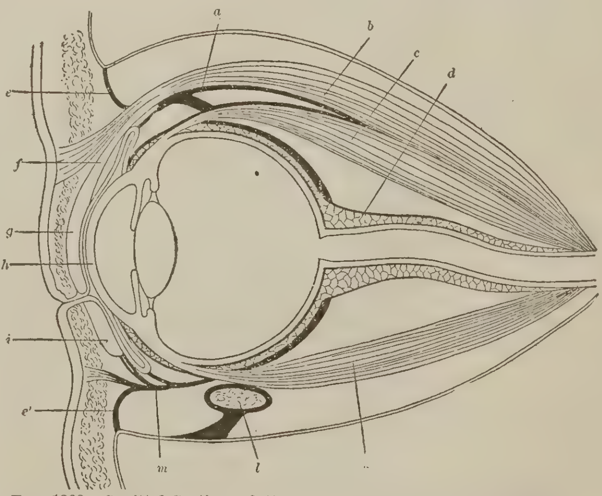


Fig. 1966.—Sagittal Section of the Eye, showing the Bulbar Fascia and its Attachments. *a*, Prolongation of bulbar fascia; *b*, levator palpebræ; *c*, rectus superior; *d*, perineural space; *e*, *e'*, septum orbitale; *f*, tendon of levator; *g*, tarsus superior; *h*, cornea; *i*, tarsus inferior; *k*, inferior rectus muscle; *l*, inferior oblique muscle; *m*, prolongation of bulbar fascia.

wandering mesenchymal cells penetrate between the retina and the lens to form the vitreous body. The interval between the layers is soon obliterated. The central artery of the retina enters the cleft back of the cup, upon the optic stalk, thus becoming finally enclosed within the optic nerve. The cleft closes early but a trace of it may often be found in the adult. If the closure is incomplete the ocular defect known as coloboma occurs, causing distortion of the pupil or a defect of the visual field.

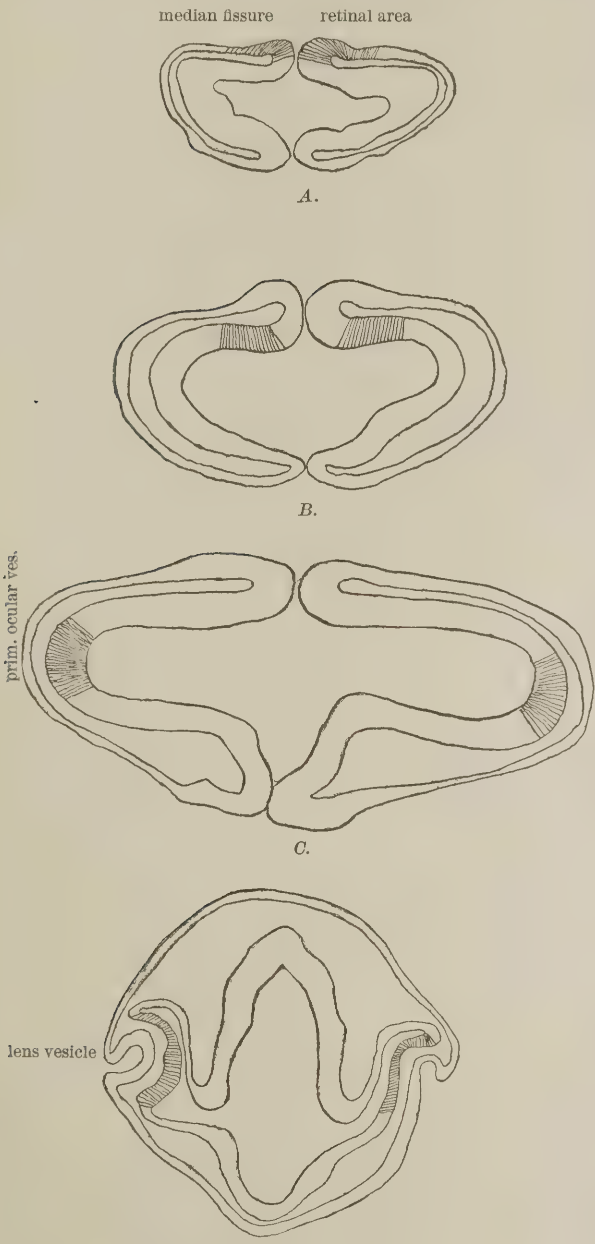


FIG. 1967.—Diagrams showing the Displacement of the Retinal Cells and their Relation to the First Cerebral Vesicle. (Dejerine.) *A* and *B* show the early development of the first primitive cerebral vesicle; *C*, the primitive ocular vesicle; *D*, the secondary ocular vesicle and the lens vesicle.

The retina develops like a part of the cerebro-spinal axis. Spongioblasts and neuroblasts arise in it, the former developing into the supporting tissue of the retina or fibres of Müller, of which the expanded bases form the internal limiting membrane, the distal, arborescent extremities the external limiting membrane in which spaces are left which eventually enclose the rods and cones. The neuroblasts appear first in the area centralis, afterward extending peripherally as far as the ora serrata. Beyond this, in the retinal layer of the ciliary region and the iris, spongioblasts alone occur. The neuroblasts develop axis-cylinder processes that grow inward along the optic stalk, gradually obliterating its cavity and constituting the optic nerve. The percipient elements (rods and cones) are the last to develop, not appearing until the fifth month in man and after birth in kittens and rabbits.

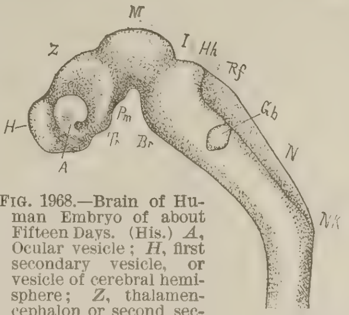


FIG. 1968.—Brain of Human Embryo of about Fifteen Days. (His.) *A*, Ocular vesicle; *H*, first secondary vesicle, or vesicle of cerebral hemisphere; *Z*, thalamencephalon or second secondary vesicle; *M*, midbrain; *I*, isthmus between mid- and hindbrain; *Hh*, fourth secondary vesicle; *N*, fifth secondary vesicle; *Gb*, otic vesicle; *Rf*, fourth ventricle; *Nk*, neck curvature; *Br*, pons curvature; *Pm*, mammillary process; *Tr*, infundibulum.

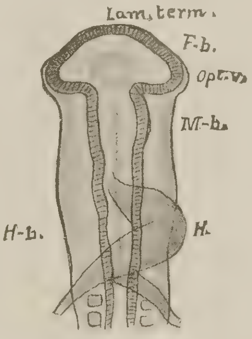


FIG. 1969.—Dorsal View of Head of Chick of Fifty-eight Hours. (Mihalkovics.) *Lam. term.*, Lamina terminalis; *F.b.*, forebrain; *Opt. v.*, ocular vesicle; *M.b.*, midbrain; *H*, heart.

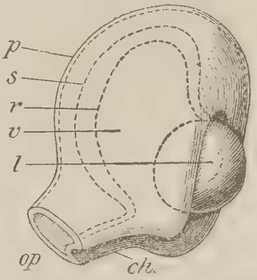


FIG. 1970.—Model showing Reconstruction of the Optic Cup. (Hortwig.) *p*, Outer wall of cup, which becomes the pigmented layer of the retina; *r*, its inner wall, which becomes the retina; *s*, temporary space between the two walls; *v*, vitreous chamber; *l*, lens; *ch*, choroid fissure; *op*, hollow stalk of cup which becomes the optic nerve.

In its early stages the lenticular vesicle is proportionately larger than at birth, filling the cavity of the optic cup so that there is but little space left between it and

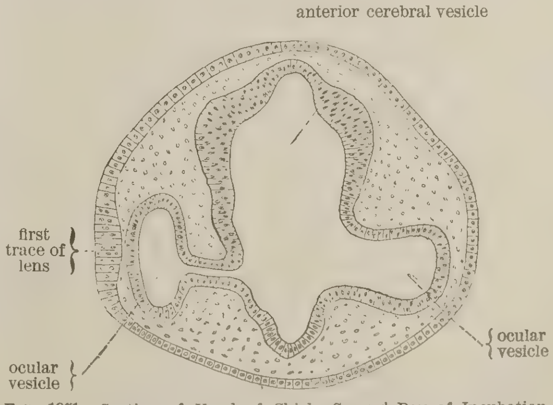


FIG. 1971.—Section of Head of Chick, Second Day of Incubation. (Duval.)

the retina. Its cells are soon arranged in a single layer, those on its outer aspect remaining cubical and forming the so-called lens epithelium; while those on the inner or retinal aspect become greatly lengthened and form the lens fibres (Fig. 1976). By this process the cavity of the vesicle is finally obliterated. At the equator or edge of the lens there is a transition region where proliferation is most active. The lens increases in size by the addition of successive layers of fibres which extend from the anterior to the posterior surface. The structureless capsule of the lens is now believed to be a product of the cells themselves and not of mesoblastic origin.

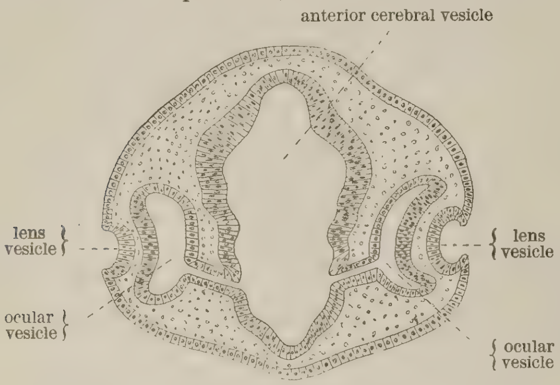


FIG. 1972.—Section of Head of Chick, Third Day of Incubation. (Duval.)

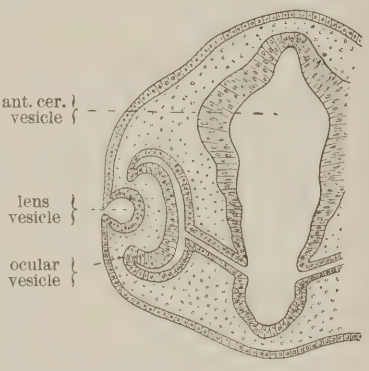


FIG. 1973.—Further Development of Retina and Lens. The lens vesicle is still attached to the epidermis. (Duval.)

Besides the capsule proper the lens is invested during fœtal life by a vascular membrane, the *tunica vasculosa lentis*. The vessels that supply this are derived from the hyaloid artery, a branch of the central artery of the retina, and from the long and short ciliary arteries that supply the iris (Fig. 1977). The supply is especially great around the equator of the lens where proliferation is active. The portion of this membrane that lies in front of the lens stretches over the pupil or mouth of the optic cup, and is known as the pupillary membrane. The tunica vasculosa begins to disappear about the seventh month, but vestiges often remain after birth.

Around the optic cup and the lens the mesoderm forms a complete investment in which two layers may be distinguished: an inner, more vascular one, which becomes the choroid coat, the choroidal part of the iris and the pupillary membrane; and an outer, less vascular one, which forms the sclera and cornea. In front of the lens a cleft appears which enlarges to become the aqueous chamber (Fig. 1978).

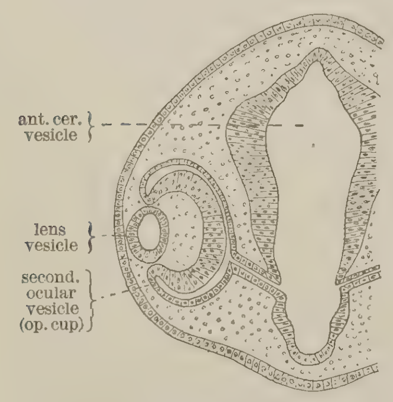


FIG. 1974.—Further Development of Retina and Lens. The lens vesicle has become entirely detached and lies at the entrance to the optic cup. The inner layer to the optic cup has begun to thicken.

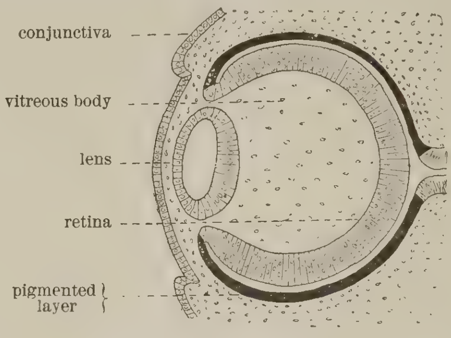


FIG. 1975.—Further Development of the Retina and Lens. The posterior wall of the lens has begun to thicken; the external layer of the optic cup is charged with pigment. (Duval.)

The eyes have first a lateral position like those of fishes, but the growth of the superior maxillary and nasal processes causes them to assume their adult situation. At first the cornea is entirely uncovered, the lids develop as folds of integument.

The nasal duct is formed in the fold between the superior maxillary and nasal processes by the canalization of a cord of infolded ectodermic cells.

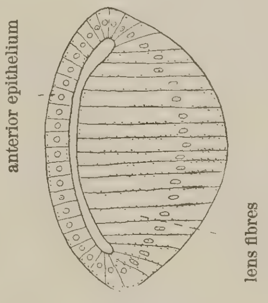


FIG. 1976.—Final Stages of Development of Lens. The cavity of the lens vesicle almost wholly disappears. (Duval.)

The Outer or Fibrous Coat.—Analogous to the dura mater of the brain, this tunic completely invests the eyeball except where penetrated by vessels and nerves. It is composed of fibrous tissue irregularly arranged behind, producing the white, opaque sclera, more regularly in front, forming the clear, transparent cornea. It is very scantily supplied with vessels and nerves, but has numerous lymph channels that appear to afford it nutrition. Associated with these and lying in the interstices of the tissue are various specific forms of corpuscles. The density and hardness of the coat efficiently protect the eye and contribute to its shape, which essentially depends, however, upon the tension produced by the enclosed contents.

The Sclera.—Four-fifths of the surface of the eyeball

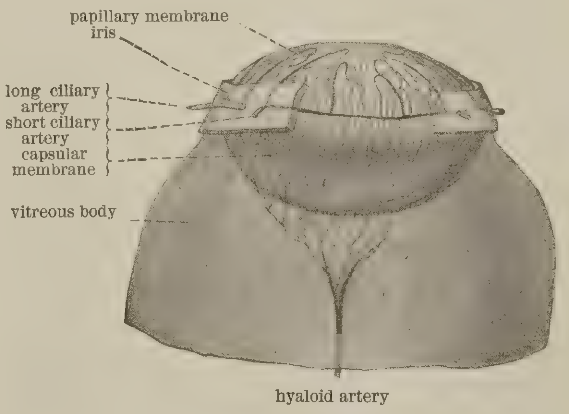


FIG. 1977.—The Vascular Tunic of the Lens in the Fœtus. (Kollman.)

is formed by the dense, opaque structure known as the "white of the eye." Its dead white appearance is due to the interference of light occasioned by the irregularly interwoven bundles of its fibres. In children and the darker races the underlying pigment shows through it slightly, giving it a bluish cast. In old persons it is yellowish from the deposit of fat within it.

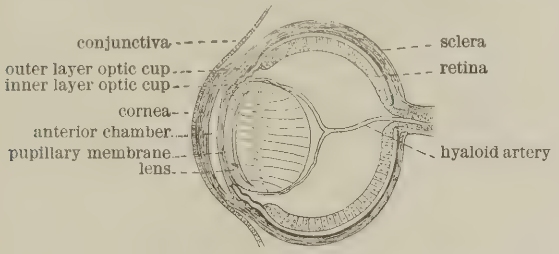


FIG. 1978.—Formation of the Anterior Chamber.

Two principal openings occur in the sclera: one in front, where the transparent cornea is set into it like the crystal of a watch into its frame, the fibres of the two mutually interblending; one behind, where the optic nerve enters at the so-called *optic canal* (optic foramen, porus opticus). Strictly speaking the sclera is not wholly deficient in the latter situation, as it is represented by a perforated sheet of connective tissue, the *lamina cribrosa*, through which the fibres of the optic nerve pass. The canal is situated about 3 mm. from the posterior pole on the nasal side and 1 mm. below the horizontal meridian. Since the fibres of the optic nerve lose their medullary sheaths as they pass forward, the canal contracts funnel-wise from without inward, terminating within in a crest-like ridge, the *pecten scleræ*. Other perforations for vessels and nerves occur, viz.: a posterior ciliary set, arranged about the optic nerve (Fig. 1979), together with those for the long ciliary vessels and nerves lying a short distance farther forward; a middle set, comprising the vorticose veins; and an anterior ciliary set a short distance behind the corneo-scleral junction.

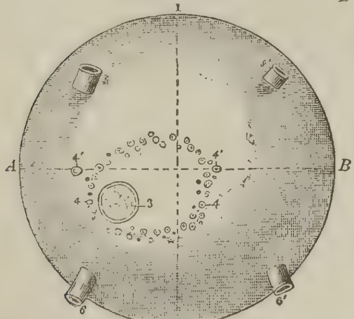


FIG. 1979.—Posterior View of Right Eye, showing Entrance of Optic Nerve. (Testut.) *A*, Nasal side; *B*, temporal side; 1, vertical meridian; 2, horizontal meridian; 3, optic nerve; 4, 4, ciliary vessels and nerves; 4′ 4′, long ciliary arteries; 5, 5′, superior vorticose veins; 6, 6′, inferior vorticose veins.

The sclera attains its maximum thickness of about 1 mm. in the vicinity of the optic nerve entrance where it is required to support the most sensitive part of the retina. It grows gradually thinner forward until, just behind the insertion of the recti muscles, it is but 0.35 mm. thick. The tendons of those muscles reinforce it to some extent and at the corneo-scleral junction it measures 0.60 mm.

The recti muscles are inserted by means of flattened expansions that blend intimately with the sclera. The adjoining sketch (Fig. 1980) shows that their insertions follow a spiral line running at a distance of 5 mm. from the corneal margin for the rectus internus, to 8 mm. for the rectus superior. The oblique muscles are inserted in the posterior hemisphere, their lines of insertion being diagonal to the meridians. The striated fibres of the inferior oblique are inserted directly upon the sclera without the intervention of a tendon.

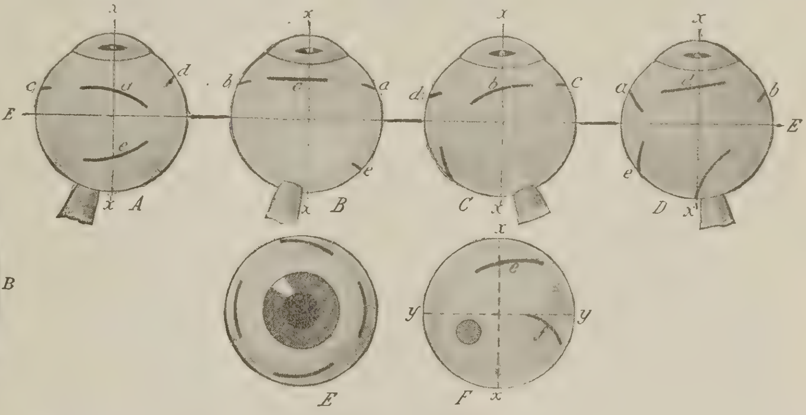


FIG. 1980.—Insertion of the Ocular Muscles upon the Sclera of the Right Eye. Drawn from the determinations of Fuchs. *A*, View from above; *B*, from nasal side; *C*, from below; *D*, from temporal side; *E*, from the front; *F*, from behind; *a*, rectus superior; *b*, rectus inferior; *c*, rectus internus; *d*, rectus externus; *e*, obliquus superior; *f*, obliquus inferior; *E E*, equator; *xx*, axis. In *F*, *y y*, horizontal meridian; *xx*, vertical meridian.

The density of the sclera is considerable, its weight being at least one-sixth that of the entire eye.

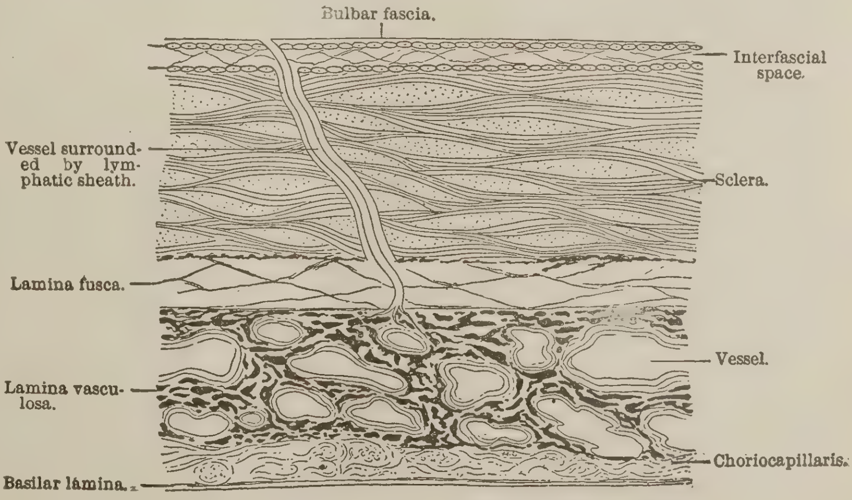


FIG. 1981.—Transverse Section of the Sclera and Choroid. (Testut.)

The sclera is a typical connective-tissue structure, being composed of white fibrous tissue with a few yellow elastic fibres intermingled (Fig. 1981). On boiling it yields gelatin. The bundles are in all parts of it irregularly arranged, though equatorial bands are more common near the corneo-scleral junction. The interstitial spaces are small and cleft like. In their walls are found fixed cells, the scleral corpuscles, in their cavities wandering leucocytes. Pigmented connective-tissue cells occur, especially in the deeper layers, where their aggregation gives a dark-brown color to the tissue, called for this reason the *lamina fusca.* Perivascular and perineural lymph channels extend from the periscleral space into the tissue along the interpenetrating vessels and nerves and communicate with a lymph space, the *perichoroidal space,* that occurs between the sclera and the choroid. It is mostly by the lymphatic circulation that the sclera is nourished, as its blood-vessels are very few.

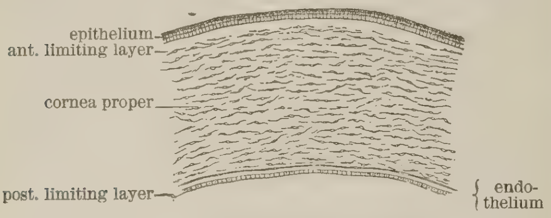


FIG. 1982.—Transverse Section of Cornea Slightly Magnified. (Gerlach.)

Near the corneo-scleral junction there occurs an equatorially extending channel called the *scleral sinus* or canal of Schlemm, that is now considered to be of a venous character. It is probably by this avenue that the aqueous humor is removed from the eye and the proper interchange of fluids effected. It appears to have no direct communication with the chambers, and the action of removal must be by intercellular filtration (Leber).

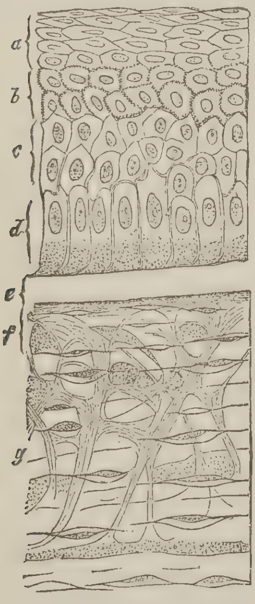


FIG. 1983.—Section through the Anterior Portion of the Cornea of the Calf. (Waldeyer.) *a*, Flattened epithelial cells; *b*, prickle cells; *c*, polymorphous cells; *d*, basal layer of club-shaped cells; *e*, anterior limiting membrane; *f* and *g*, substantia propria of cornea.

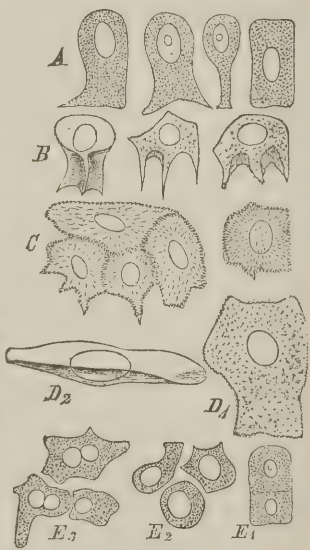


FIG. 1984.—Isolated Cells from the Corneal Conjunctiva. (Waldeyer.) *A*, From the basal layer; *B*, polymorphous cells; *C*, prickle cells; *D*, flattened cells; D_1, plane view; D_2, side view; *E*, young cells from the middle layers; E_1, cell undergoing division; E_2, cells with one nucleus; E_3, multinucleate cells.

The nerves supplying the sclera are few in number and are derived from the ciliary nerves.

The Cornea.—This is also a connective-tissue structure formed of superposed and anastomosing lamellæ, closely applied to each other and with no substance intervening that can vary the refractive force of its fibres. Although composed of many different units—epithelium, limiting membranes, successive layers of connective tissue, lymph channels, corpuscles and nerves—all have the same index of refraction and the membrane is perfectly transparent. A slight disturbance tending to derange its mechanical adjustment, such as compression or other strains, the absorption of fluids, etc., at once beclouds it.

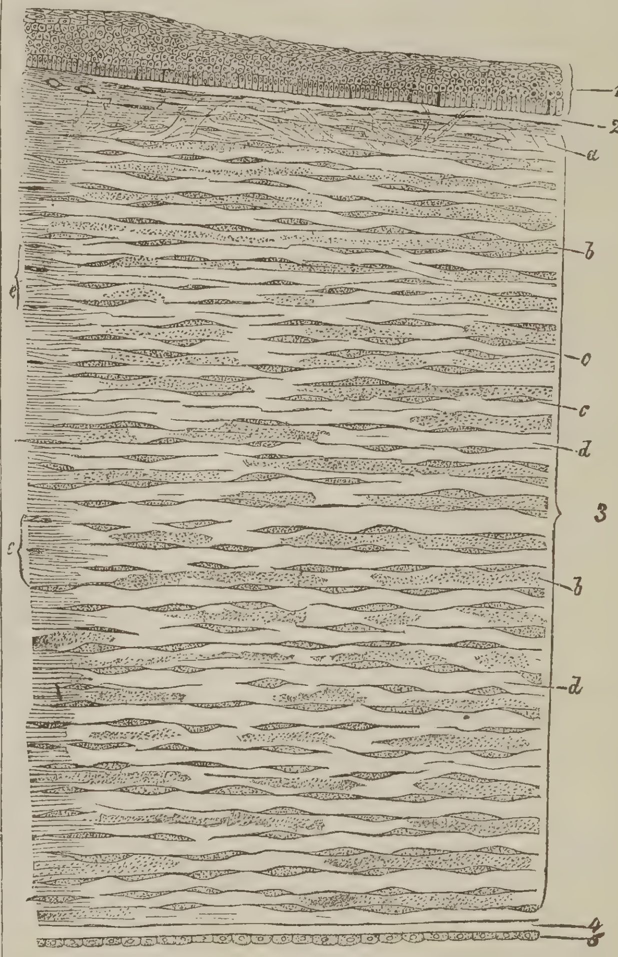


FIG. 1985.—Section through Human Cornea. (Waldeyer.) 1, Conjunctival epithelium; 2, anterior limiting membrane; 3, substantia propria; 4, posterior limiting membrane; 5, endothelial layer; *a*, fibres from anterior limiting membrane entering substantia propria; *b*, fibres cut transversely and fasciculi; *c*, corneal corpuscles; *d*, fasciculi cut lengthwise and therefore appearing homogeneous; *e*, *e*, corneo-scleral junction.

The history of its development shows that its layers may be classified according to their sources: (1) *conjunctival*, forming the exterior layer of epithelium, derived from the ectoderm; (2) *scleral*, forming the main portion of the structure together with its anterior limiting membrane, derived like the sclera from the mesoderm (mesenchyme); (3) *choroidal*, forming the endothelium lining the anterior chamber together with the posterior limiting membrane, also of ectodermic origin but correlated with the middle tunic of the eye.

Set like a window in the frame of the sclera its outline is slightly elliptical, its horizontal diameter being 11.6

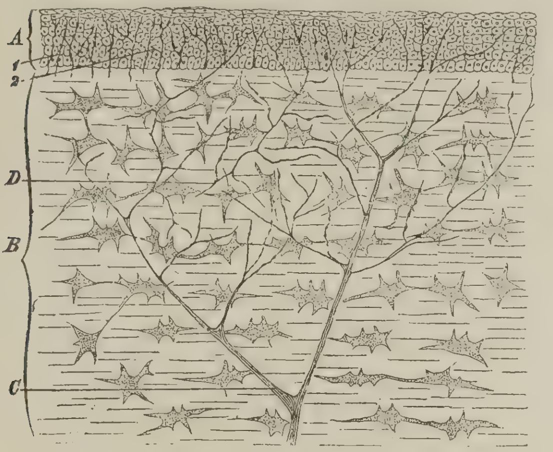


FIG. 1986.—Section of Human Cornea Stained with Chloride of Gold, showing the Corneal Corpuscles and Nerve Endings. (Waldeyer.)

mm., while its vertical one is but 11 mm. The outer and inner surfaces are unequally curved, the inner one having nearly the curvature of a sphere with a radius of 6 mm., while the outer one has that of an ellipsoid with a horizontal radius of 7.8 mm., and a vertical one of 7.7 mm., even greater variations being frequently observed. The surfaces therefore are not parallel, and the thickness of the cornea varies from 1.1 mm. at its periphery to 0.9 at the ocular axis. It attains its permanent dimensions early; its weight averages 180 mgm., one-fortieth that of the entire eye; and its specific gravity is 1.076 (Davy). Its index of refraction is 1.3523, that of distilled water being 1.3358 (Krause). When boiled it yields a form of chondrin instead of gelatin as does the sclera. Its percentage of water is 72.75.

The main substance of the cornea is a lamellated connective tissue lined both without and within by clear structureless limiting membranes, then clothed without by the epithelium of the conjunctiva, within by the endothelium of the anterior chamber. Thus there are five varieties of tissue to be considered (Fig. 1982).

The corneal conjunctiva is an epithelium corresponding with that of the general surface of the body, but having fewer layers of cells and no corneous layer. The deeper cells are expanded at the base and show signs of mitotic division (see Figs. 1983, 1984). Those of the middle layer ("prickle cells") are surrounded by intercellular passages that permit the circulation of lymph.

The anterior limiting membrane (Bowman's membrane, anterior elastic lamina) is a clear anhistous sheet that lines the cornea under the conjunctiva up to near the margin, sending down into the deeper layers fibres of a similar character. It behaves with reagents like the spiral fibres that encircle connective-tissue bundles, not dilating when treated with acetic acid, and resembles the subepithelial basement layer of many membranes.

The proper tissue of the cornea presents from sixty to sixty-five lamellæ (Fig. 1985) composed of flattened bundles of white fibrous tissue arranged nearly at right angles to each other. Between these is an intricate system of interfascicular spaces or lymph lacunæ connected with each other by fine canals and containing fixed cells, the corneal corpuscles (Fig. 1986). These have a resemblance to the osteoblasts of bone in that they occupy interstitial spaces and apparently send fine branching processes along delicate canals that communicate with other spaces. Wandering cells are also found in the passages of the cornea. At the corneal margin these passages communicate with similar ones in the sclera.

The posterior limiting membrane (membrane of Descemet, of Demours, of Duddell, posterior elastic lamina) is also an anhistous layer but apparently quite different in character and origin from the anterior limiting membrane. Its increase with age, and certain irregularities found on its surface lead to the conclusion that it is produced by the endothelial cells which it supports. At the margin of the cornea it becomes thickened into a ring-like zone, the *annular ligament*, beyond which it can be traced over to the insertion of the iris, as a series of distinct bundles of fibres, the *pectinate ligament*, separated by minute clefts, the *spaces of Fontana* (Fig. 1987).

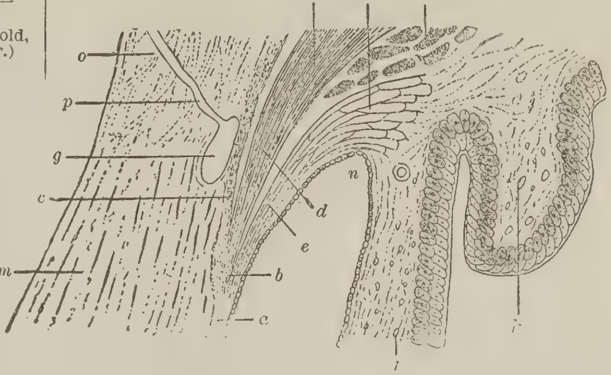


FIG. 1987.—Meridional Section Showing the Connection Between the Cornea and the Middle Coat of the Eye. (Testut.) *a*, Posterior limiting layer; *b*, annular ligament; *c*, scleral fibres; *d*, ciliary fibres; *e*, posterior fibres forming the pectinate ligament; *f*, Fontana's space; *g*, scleral sinus; *h*, meridional fibres of the ciliary muscle; *i*, annular fibres of same; *k*, ciliary process; *l*, iris; *m*, cornea; *n*, angle of the iris; *o*, sclera; *p*, scleral vein.

The endothelium that forms the posterior boundary of the cornea is a flattened single layer of cells similar to those usually lining serous cavities. It is continuous

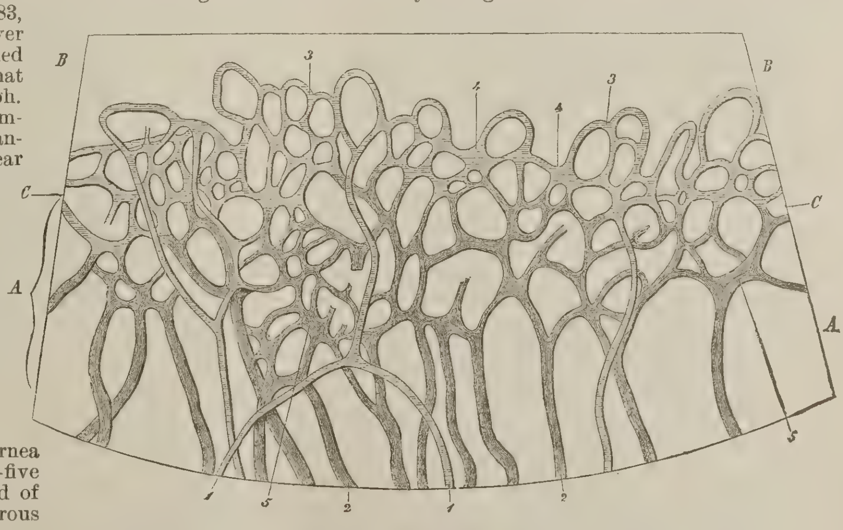


FIG. 1988.—The looped Marginal Plexus at the Periphery of the Cornea. (Waldeyer.)

over the acute peripheral portion of the anterior chamber (known as the *angle of the iris*) with the endothelium lining the anterior surface of the iris.

In the healthy cornea there are no blood-vessels, except just at the margin where vessels from the sclera form a looped network (Fig. 1988). Notwithstanding this wounds of the cornea heal rapidly, nutrition being afforded by the copious supply of lymph.

The nerves that supply the cornea are derived from the anterior ciliary set which form, near the corneoscleral junction, a close-meshed plexus, the *plexus annularis*, from which sixty to eighty nerves, containing both medullated and non-medullated fibres, pass to the cornea, two-thirds going toward the anterior surface. They soon lose their medullary sheaths and form a second plexus, the *deep stroma plexus* (primary plexus, fundamental plexus) (Fig. 1989). Reaching the anterior limiting membrane, perforating fibres from this plexus penetrate that layer and unite to form a third or *subepithelial plexus* from which again fibres pass between the epithelial cells, forming a fourth, or *intra-epithelial plexus*. From this as well as from the subepithelial plexus terminal filaments are given off on which are formed end organs shaped like rounded bulbs, hooks, loops, and platelets. So rich is this supply that it appears probable that every epithelial cell is in actual contact with a nerve fibre or its terminal.

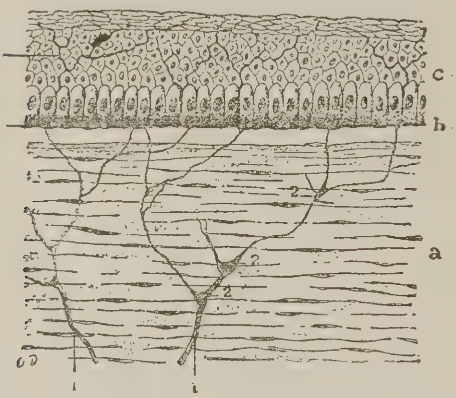


FIG. 1989.—Nerve Plexuses of the Cornea. (Testut.) 1, 1, Two afferent nerve trunks; 2, deep stroma plexus; 3, subepithelial plexus; 4, intra-epithelial plexus; *a*, cornea proper; *b*, anterior limiting membrane; *c*, anterior epithelium.

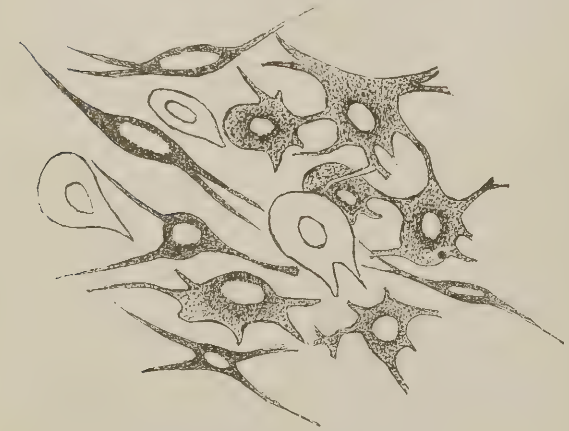


FIG. 1990.—Branched Cells of the Choroid.

The Middle or Vascular Coat.—Considered from an embryological point of view this coat is properly divided into four regions: (1) The choroid proper, comprising the pigmented vascular membrane that extends from the optic-nerve entrance as far as the boundaries of the visual retina where it is limited by a crenulate line called the *ora serrata;* (2) the ciliary choroid, or ciliary body, a thickened portion containing muscular fibres and vascular plexuses; (3) the choroidal part of the iris, comprising the greater portion of the colored curtain which is stretched in front of the lens; (4) the corneal choroid, comprising the corneal endothelium lining the anterior chamber and its product, the posterior limiting membrane. These last have already been described.

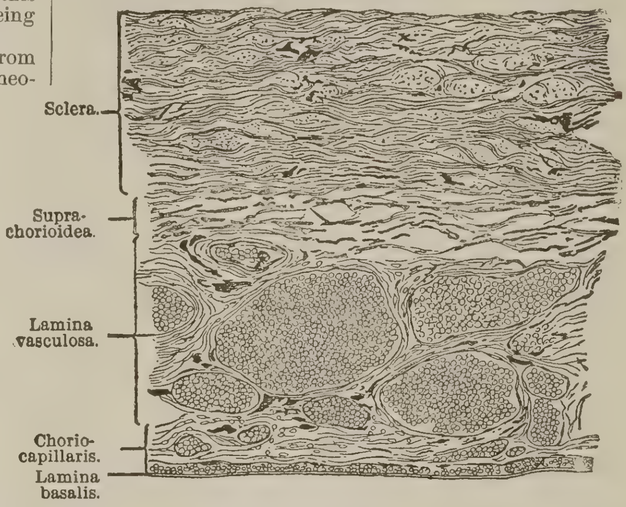


FIG. 1991.—Section of the Human Choroid. (Böhm and von Davidoff.)

This coat generally offers a marked contrast to the other two by its vascular and pigmented character, and has been compared to the pia mater of the brain. Its function is essentially nutritive, and it supplies the fluids that fill the eyeball and preserve its tension. It is soft, yielding, and easily torn or injured.

The Choroid Proper.—This portion of the middle coat, covering about two-thirds of the eyeball, is a loose, vascular, extensible tunic about 0.1 mm. in thickness at the optic-nerve entrance, thinning gradually to about half that at the ora serrata. It is imperfectly separated from the sclera by the suprachoroidal space, intervening bands of fibrous tissue as well as numerous perforating vessels and nerves uniting the two. Its inner surface is smooth and closely applied to the pigmented layer of the retina.

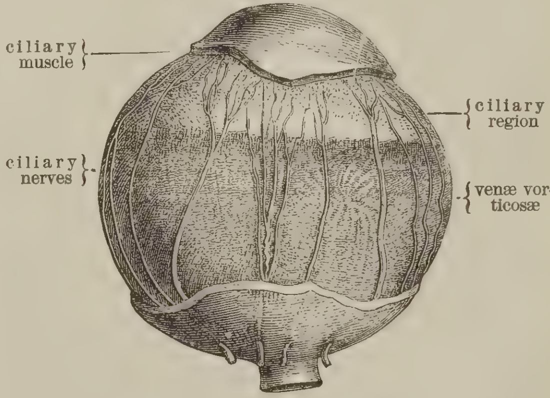


FIG. 1992.—The Choroid Viewed from its Outer Surface. (Merkel.)

Its color, depending on the pigment deposited in its cells and the amount of blood in its vessels, is a dark or reddish-brown, somewhat lighter in the old than in the young.

The general substance or *stroma* of the choroid is composed of interwoven trabeculæ of connective tissue, both white and elastic, supporting a large number of blood-vessels and containing many irregularly branched, pigmented cells (Fig. 1990). The outer layer, being more loosely woven and containing fewer vessels, is known as the *lamina suprachoroidea;* that next to it, containing the largest vessels, is the *lamina vasculosa;* the next layer having an extremely rich network of capillaries is the *lamina choriocapillaris;* while the anhistous limiting membrane that separates this from the retina is the *lamina basalis* (Fig. 1991).

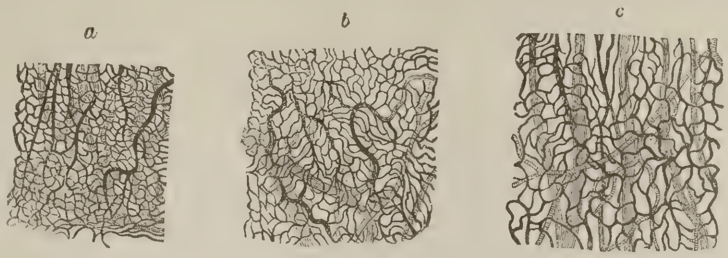


FIG. 1994.—The Capillary Network of the Choroid. *a*, Near the optic-nerve entrance; *b*, about the equator of the eyeball; *c*, near the ora serrata. The veins are striated longitudinally, the arteries transversely, the capillaries are black. The latter are only half as broad as they ought to be.

While the suprachoroidea is not itself remarkably rich in vessels and nerves, its loose tissue affords an avenue by which they readily penetrate to their ultimate destinations. The long ciliary arteries and nerves lie almost wholly in this layer in their transit forward to supply the iris and neighboring structures (Fig. 1992).

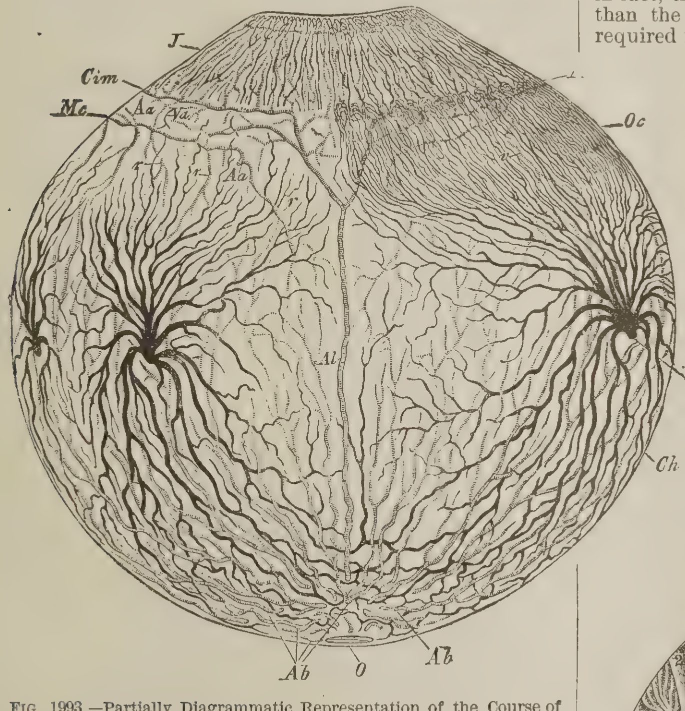


FIG. 1993.—Partially Diagrammatic Representation of the Course of the Vessels in the Choroid. (Leber.) *Ch*, choroid; *J*, iris; *Mc*, ciliary muscles; *Pc*, ciliary processes; *Oc*, ciliary ring; *O*, optic nerve entrance; *Ab*, short posterior ciliary arteries; *Al*, long posterior ciliary arteries; *Aa*, anterior ciliary arteries; *Cim*, greater arterial circle of iris; *Vv*, vorticose veins; *r*, *r*, recurrent arteries.

The arteries of the lamina vasculosa (Fig. 1993) are derived mainly from the short ciliary set that penetrate the ball by about twenty small branches in the vicinity of the optic nerve. The main vessels of this layer are, however, the vorticose veins, from four to eight large trunks formed by converging whorls of vessels. They are usually arranged in a nearly symmetrical manner in four sets nearly ninety degrees apart, and penetrate the sclera obliquely near the equator. Owing to this oblique penetration their discharge is liable to be interfered with by pressure from without, particularly from the action of the ocular muscles. In the deepest part of this lamina are found wavy bundles of elastic tissue, a vestige of the *tapetum* that causes the metallic sheen observed in the eyes of many lower animals under certain conditions of reflected light.

The choriocapillaris or membrane of Ruysch (Fig. 1994) is a close-meshed network of capillaries, so close, in fact, that the space occupied by the vessels is greater than the intervals between them. This appears to be required for the nourishment of the closely contiguous percipient layer of the retina, *i.e.*, the rods and cones, to which the proper arteries of the retina do not penetrate. The vorticose veins begin in this layer by capillary whorls, sometimes called the *stars of Winslow* (Fig. 1995).

The basilar lamina, also known as the vitreous membrane, or the membrane of Bruch, is structureless or nearly so, and appears to be analogous to the basement membrane of epithelium.

The long and short ciliary nerves send vaso-motor twigs to the choroid, and lymphatics gather fluid from its numerous interspaces.

The Ciliary Body.—The wavy line of the ora serrata marks the limit of the layer of rods and cones of the retina and of its trophic layer, the choriocapillaris (Fig. 1995). From this line to the border of the iris curtain the middle tunic of the eye is marked by finely radiate striæ resembling cilia, hence the name that has been applied to this region. The posterior portion,

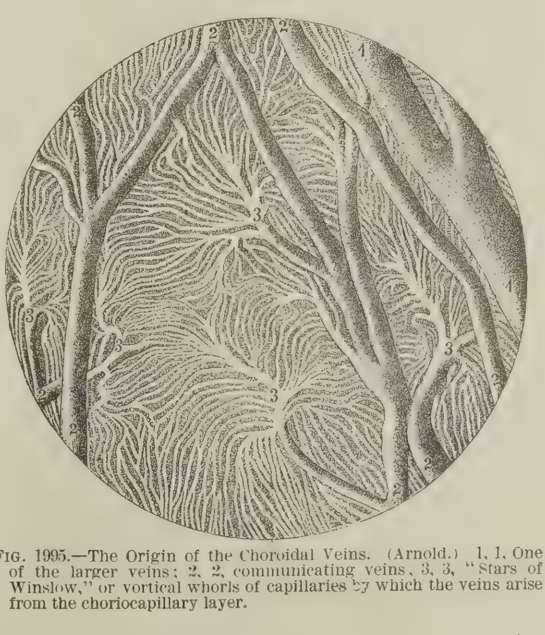


FIG. 1995.—The Origin of the Choroidal Veins. (Arnold.) 1, 1, One of the larger veins; 2, 2, communicating veins, 3, 3, "Stars of Winslow," or vortical whorls of capillaries by which the veins arise from the choriocapillary layer.

comparatively smooth, is known as the *ciliary ring* or orbiculus ciliaris; the anterior portion, thickened and plicated in a meridional direction, is known as the *corona radiata.* Between these and the sclera, in the more superficial portion of the middle coat, lies an annular band of muscular tissue, known collectively as the *ciliary muscle.*

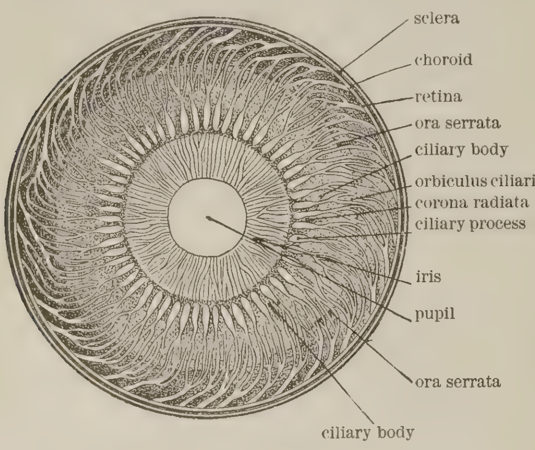


FIG. 1996.—The Ciliary Body as Seen from Behind. × 3.

The ciliary ring, about 4 mm. broad, is formed of nearly straight, unbranched vessels for conveying blood either forward to the corona radiata or backward to the vorticose veins, united by a loose stroma like that of other portions of the middle coat. The basilar layer is continued forward and is even somewhat thickened.

The corona radiata is the zone lying between the margin of the ciliary ring and the outer margin of the iris. It derives its name from the radiate arrangement of its characteristic features, the *ciliary processes,* club-shaped plications from 2 to 3 mm. in length and 0.12 mm. wide, that lie in a meridional direction (Fig. 1997). They resemble the glomeruli of the kidney in containing convoluted blood-vessels, and doubtless assist in the production of the aqueous humor. The suspensory ligament of the lens (zonula ciliaris) extends backward over them as far as the ora serrata, some of its fibres springing directly from the stroma of the processes. A marked interval separates the corona from the iris.

The ciliary muscle (Fig. 1998) occupies a zone 6 to 7 mm. in width and triangular in meridional section, reaching a maximum thickness of 0.8 mm. It takes its origin from the annular ligament and the sclera in the neighborhood of the scleral sinus and is inserted upon the stroma of the middle coat in the region of the ciliary body and beyond. Its most superficial fibres are directed meridionally and constitute the *tensor choroidea* of Brücke; those next succeeding approach more and more a radial direction as they get deeper; and the deepest of all are arranged equatorially, constituting the *compressor lentis* of H. Müller. The office of the muscle is to draw the choroid forward and thus relax the suspensory ligament of the lens, which, being no longer held tense, assumes a more convex shape suitable for the refraction of diverging rays from objects near at hand. In myopic eyes the circular fibres are fewer in number or wanting, while in hypermetropic eyes they are greatly increased.

Many ancient anatomists (Eustachius, Scheiner, Plempius, Descartes) suspected that this structure was muscular, but the first to demonstrate it from actual microscopic examination appears to have been an American oculist, William Clay Wallace of New York City, who, in 1835, published in the *American Journal of Sciences and Arts* an article "On the Accommodation of the Eye to Distances," saying:

"At the base of the ciliary processes, upon the inner surface of the choroid coat, there is a range of muscular fibres. In the sheep the fibres of the upper portion run transversely to the ciliary processes; those of the lower portion run parallel to them."

Brücke, to whom the credit of the discovery of the meridional fibres is usually given, did not describe the muscle until 1846, and H. Müller, usually credited with the discovery of the equatorial fibres, published first in 1855.

The muscle is supplied by the long ciliary nerves from the nasal branch of the ophthalmic and by the short ciliary from the ciliary ganglion. These form within the substance of the muscle a ring-like plexus, the *ciliary plexus* (orbiculus gangliosus), from which pass fibres of apparently motor function, ending free between the muscle cells, vaso-motor fibres, and also sensory fibres with terminal end organs. Some of the latter are believed to impart an accurate appreciation of the contraction of the muscle.

The Iris.—This colored diaphragm, pierced with its central aperture, the pupil, hangs freely but not quite vertically in the aqueous chamber, its outer or ciliary border attached just behind the corneo-scleral junction, and its free or pupillary border resting a little anterior to the other upon the lens. Behind, its tissue is continuous with that of the ciliary body, in front with that of the pectinate ligament and the angle of the iris.

Its diameter is from 10 to 12 mm., its thickness 0.4 mm. when lax, increasing to double that amount when contracted. The pupil, slightly eccentric toward the nasal side, varies from 1 to 8 mm. in diameter, according to the state of contraction of the iridial muscles.

It will be remembered that the pupillary border of the iris forms the edge of the optic cup, which here doubles back upon itself and becomes invested by the vascular, mesodermal layer that produces the choroid. Hence the iris is composed of two genetically distinct portions: a retinal one, secondarily derived from the ectoderm, belonging to the optic cup proper; and a choroidal one, mesodermic in origin (Fig. 1999). Since the retinal portion contains no percipient elements it will be convenient to consider all together.

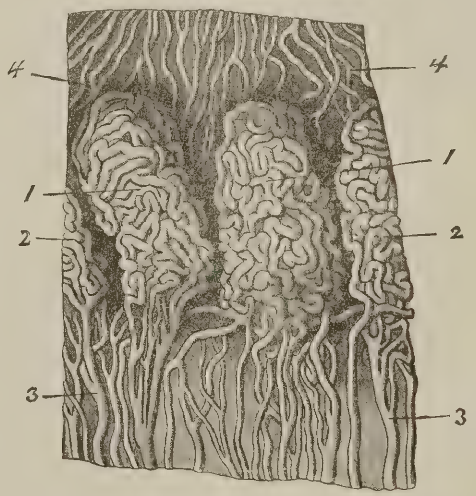


FIG. 1997.—Injected Ciliary Processes Viewed from Behind. (Sappey.) 1, 2, Venous plexuses composing the bulk of the projections; 3, 3, efferent trunks tributory to the vorticose veins; 4 4, venous radicles from the iris. × 40.

Viewed closely, the anterior surface will be seen to present two concentric zones, *pupillary* and *ciliary,* separated by a festooned line, the *lesser arterial circle,* that indicates the former attachment of the pupillary membrane (Figs. 2000 and 2001). Both zones are marked by radial striæ, caused by vessels and nerves: those of the pupillary zone being fine and close, *radii minores;* those of the ciliary zone larger, *radii majores.* The pupillary border shows a thin black line slightly beaded where the striæ reach it. In the pupillary zone there are found between the striæ minute clefts that penetrate the stroma and communicate with lymph spaces. The ciliary zone is furrowed by concentric ridges that indicate where folds are formed during dilatation.

Pigmented cells scattered through the stroma impart color. When these are scanty the pigment of the posterior epithelium shows through, producing the color characteristic of blue or gray eyes according to the thickness of the translucent stroma. The stroma pigment is scattered in flecks, producing various tints of green, yellow, or brown which when very deep is called black. In albinos pigment is absent even in the posterior epithelium and the iris appears reddish from the hue of its blood-vessels.

The posterior surface (Fig. 2002) presents a series of radial ridges cut by concentric lines into rectangular spaces. Within the pupillary zone these ridges (*contraction folds*) are increased in number. The color of the posterior surface is normally uniform and dark from the pigmented retinal epithelium.

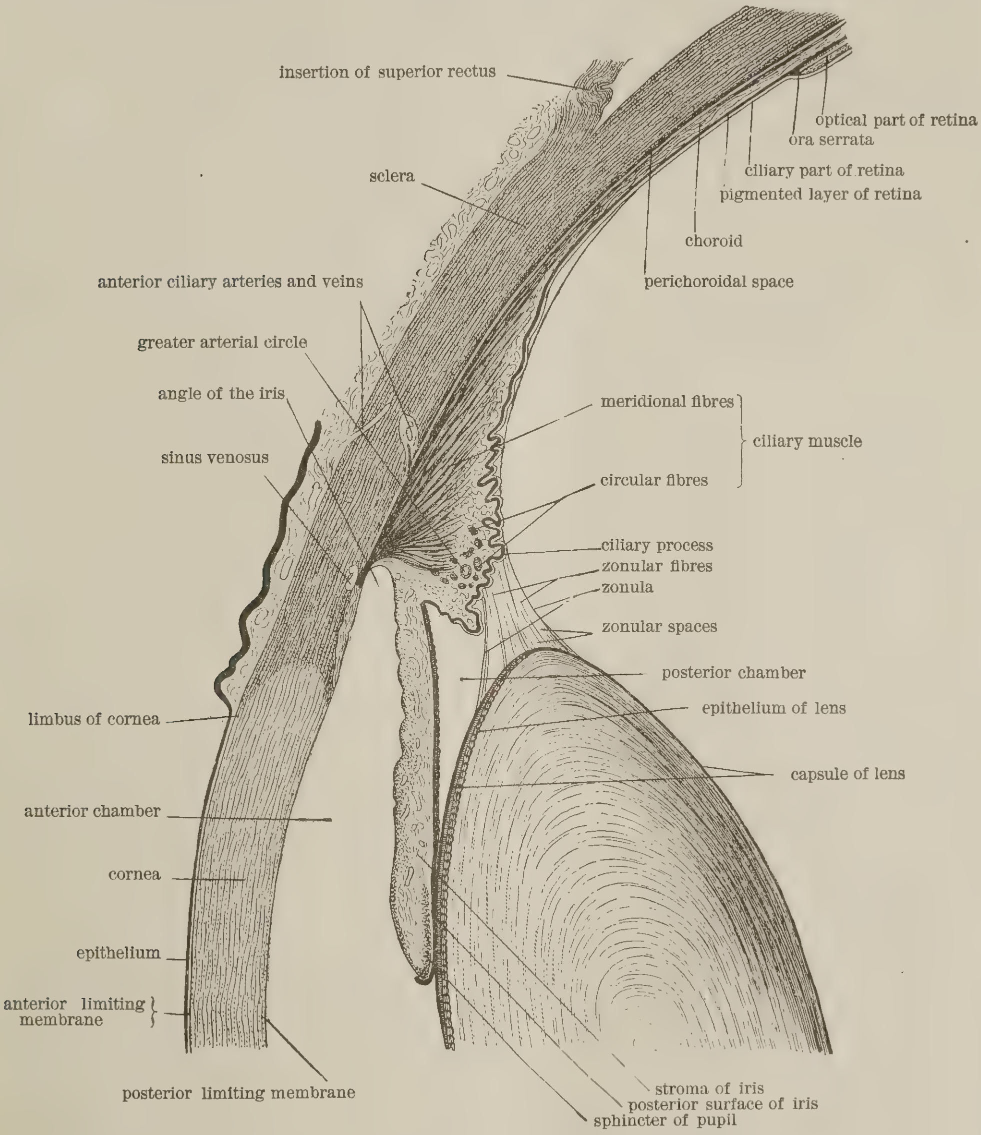


FIG. 1998.—Meridianal Section of a Portion of the Anterior Part of the Eyeball. (Toldt.)

In minute structure the iris consists of a choroidal portion, composed of a loose stroma condensed both externally and internally to a boundary membrane and clothed also anteriorly with the endothelium of the anterior chamber, and of a retinal portion, composed of two layers of pigmented cells corresponding to the doubled margin of the optic cup.

The anterior epithelium, clear and transparent, is like that lining the posterior surface of the cornea.

The anterior boundary layer is composed of delicate interlacing bundles essentially similar to the connective tissue of the stroma.

The stroma is much like that of the choroid, being composed of numerous vessels and nerves united by loose connective tissue, with interstitial lymph spaces and muscular fibres. The latter are condensed near the pupillary margin to an annular band, the *sphincter pupillæ,* while an imperfect layer of radially arranged bundles stretching from the sphincter to the pectinate ligament constitutes the *dilatator pupillæ*. The long controversy regarding the existence of these fibres, which are very difficult to demonstrate in the pigmented iris, may now be regarded as settled. The sphincter appears to be controlled by the oculo-motor nerve, the dilatator by the sympathetic.

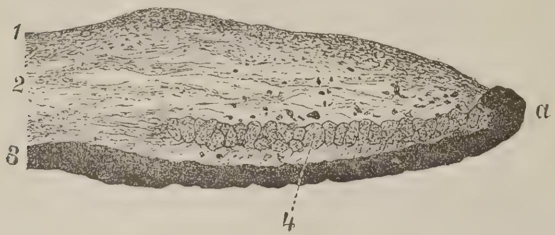


FIG. 1999.—Meridional Section through the Pupillary Zone of the Human Iris. *a*, Pupillary border formed of epithelium, arranged in bead-like processes; 1, anterior limiting layer; 2, stroma or vascular layer; 3, pigmented epithelium, continuous behind with the retina; 4, sphincter pupillæ.

The posterior boundary layer is a continuation of the basilar lamina of the choroid and like it is a very thin structureless membrane formed by condensation of the connective tissue of the stroma.

The epithelium of the retinal portion of the iris is in two layers, of which the outer is composed of fusiform cells, the inner of columnar cells. Both of these are densely crowded with pigment.

A vascular network, the greater arterial circle (Fig. 2003), formed by branches of the anterior and long ciliary arteries, lies at the ciliary border of the iris between the two portions of the ciliary muscle. From this arterioles pass radially toward the pupil and on reaching the sphincter unite in another anastomosis, the lesser arterial circle, from which are given off vessels that supply the pupillary zone and the pupillary membrane of fœtal life. Venules from these networks pass radially outward and finally discharge into trunks that reach the vorticose veins.

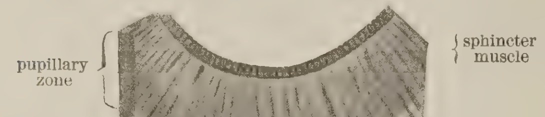


FIG. 2000.—Segment of Anterior Surface of Iris with Pupil Contracted. × 20. (Fuchs.)

There are abundant lymph spaces within the stroma of the iris, but no lymphatic vessels properly speaking.

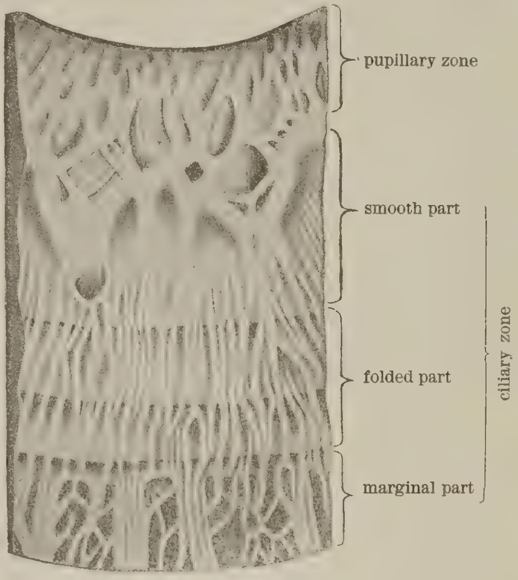


FIG. 2001.—Segment of Anterior Surface of Iris with Pupil Dilated. × 20. (Fuchs.)

The nerves of the iris are derived from the ciliary plexus. Their fibres, as they proceed toward the pupillary border, form a coarse meshwork from which are derived motor nerves with ultimate filaments that supply muscle cells, vaso-motor nerves, and sensory nerves that lie immediately under the anterior endothelium.

The Inner or Nervous Coat.—Being formed from the duplicate, invaginated layers of the optic cup, originally an outgrowth from the brain, the structure of this coat bears some analogy to that of the cerebral cortex. As the ventricles of the brain are lined with epithelium (ependyma), so the lining of the cavity of the optic vesicle, originally continuous with them, retains an epithelial character. By the invagination of the optic cup this cavity becomes obliterated, but the boundary lining remains as the two outer layers of the retina. The outermost of these is a single layer of highly pigmented epithelium; the inner one becomes, for a region extending from the optic-nerve entrance to the ora serrata, a highly specialized neuro-epithelium reinforced by a large number of nervous elements, while over the ciliary region and the iris it too

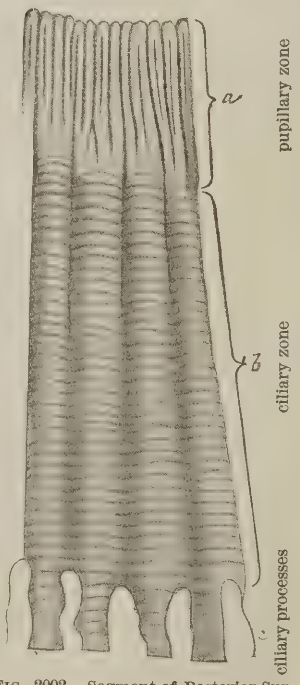


FIG. 2002.—Segment of Posterior Surface of Iris, Medium Dilatation of Pupil. × 25. (Fuchs.)

is reduced to a single layer of simple epithelium, non-pigmented in the former, pigmented in the latter region.

We may therefore distinguish three retinal regions: (1) The retina proper, or percipient retina; (2) the ciliary retina; and (3) the iridian retina. The last has already been described.

The Retina Proper is a smooth tunic that covers the posterior two-thirds of the interior of the eyeball, reaching to about 5 mm. from the attachment of the iris. When the interior of the eye is viewed by the ophthalmoscope it appears reddish from the blood-vessels that ramify in the innermost layers. Its thickness varies from 0.4 mm. behind to half that near the ora serrata. Its outer epithelial layer is deeply pigmented, the remainder perfectly transparent unless deprived of light, when it assumes a purplish hue due to a diffused coloring matter known as the visual purple. Its transparency ceases after death and sometimes during life from pathological causes. It is also normally obscured where the fibres of the optic nerve enter—the *optic disc*, and in an elliptical area lying in the optical axis—the *yellow spot*.

The optic disc (optic papilla, porus opticus), situated 1 mm. below the horizontal meridian and 3 mm. to the nasal side of the vertical meridian, is nearly circular in form with a diameter of from 1.4 to 1.7 mm. As the optic fibres pass through the lamina cribrosa they lose their medullary sheaths and diverge, causing a depression near the centre of the disc, termed the *excavation*. The myelin of the deep fibres shining through its transparent surface gives a whitish appearance to the disc and the free edges of the sclera and choroid are seen as boundary rings. The central artery of the retina entering at the excavation ramifies upon its surface. There being no percipient elements in this area it is insensible to light, and is hence sometimes called the punctum cæcum or blind spot.

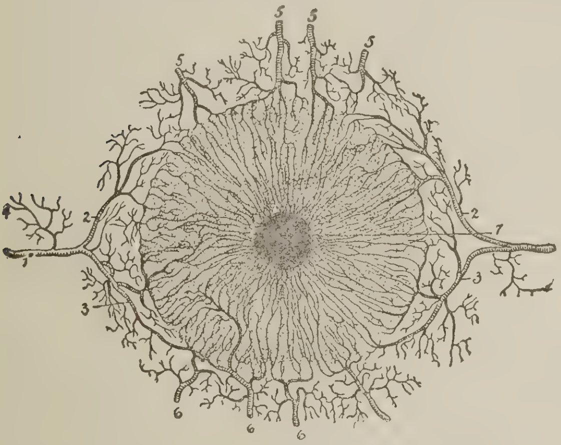


FIG. 2003.—Arteries of the Iris. (Sappey.) 1, 1, long posterior ciliary arteries; 2, 3, their branches of bifurcation; 4, recurrent arteries destined for the choroid; 5, 5, 6, 6, anterior ciliary arteries anastomosing with the long ciliary to form the greater arterial circle of the iris; 7, the lesser arterial circle of the iris.

The yellow spot (macula lutea, spot of Sömmering) is a reddish-brown area nearly circular in form, about 2 mm. in diameter. Near its centre it has a depression termed the central fovea (fovea centralis), 0.02 to 0.4 mm. in diameter, which is the seat of the most acute vision. The percipient elements have here a special arrangement which will be hereafter explained.

The retina being the only sense organ directly derived from the cerebral cortex, shows combined within it structures usually widely separated. Its cells are arranged in three layers that communicate with each other in a chain-like series: (1) collective, comprising the neuro-epithelium of the rods and cones that receive the primary impulses leading to vision; (2) transmittive, bipolar cells sometimes collectively called the ganglion of the retina; (3) liminal, large multipolar cells lying near the inner surface of the retina and sending fibres brainward through the optic nerve.

Similar members exist in other sense organs; thus, in the organs of common sensation we have: (1) the epithelium surrounding the nerve terminal in the skin; (2) the cells of the spinal ganglia, conveying the impulses to the nervous centres; (3) the cells of the receptive nuclei in the spinal cord or the medulla oblongata.

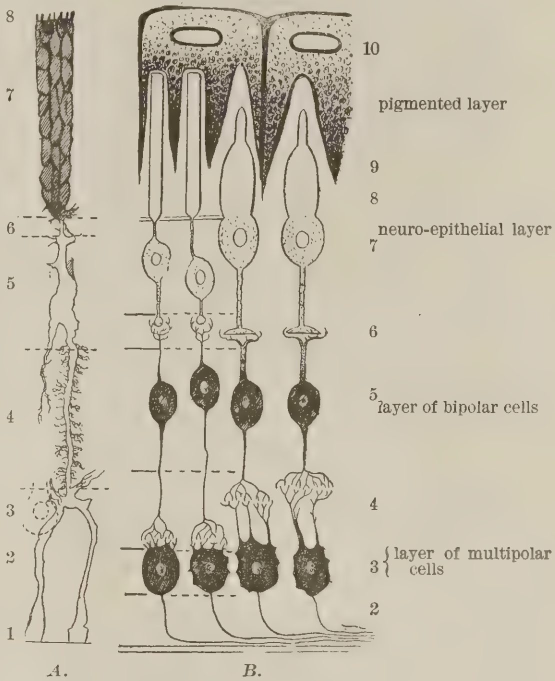


FIG. 2004.—Schema Showing the Arrangement of the Structural Elements of the Retina. A, Fibre of Müller; B, nerve and epithelial cells. 1, Membrana limitans interna; 2, layer of nerve fibres; 3, ganglionic layer, 4, inner molecular layer; 5, inner nuclear layer; 6, outer molecular layer; 7, outer nuclear layer; 8, membrana limitans externa; 9, layer of rods and cones; 10, pigmentary layer.

Besides the elements of the retina already mentioned, which are doubtless the main apparatus by which visual sensations are conveyed, there are certain associative cells that probably serve to correlate and co-ordinate the action of the separate neural chains.

All these may be considered active elements. There are also, in the central nervous system, certain passive or sustentacular elements. These, known in other regions as neuroglia cells, are in the retina called the fibres of Müller.

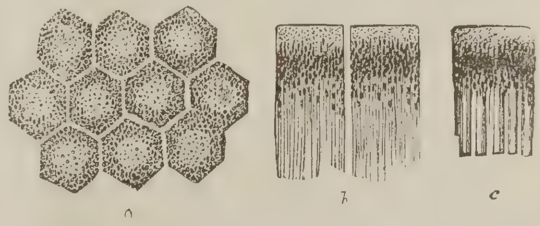


FIG. 2005.—Cells of Pigment Epithelium from the Human Retina. (Max Schultze.) *a*, Surface view; *b*, side view showing fringe-like processes that extend toward the layer of rods and cones; *c*, a cell to which the outer portions of some rods are attached.

The retina is often described as consisting of from nine to eleven layers. There seems to be no good reason for this, as some of the appearances described as layers are caused by the intermingling processes of cells, while others, the so-called limiting membranes, are expansions from the supporting cells or fibres of Müller. Morphologically speaking there are but four layers, the three already mentioned and the external layer of pigmented epithelium. The accompanying diagram presents both the older and the more recent nomenclature (Fig. 2004). The layers will be described in succession from without inward.

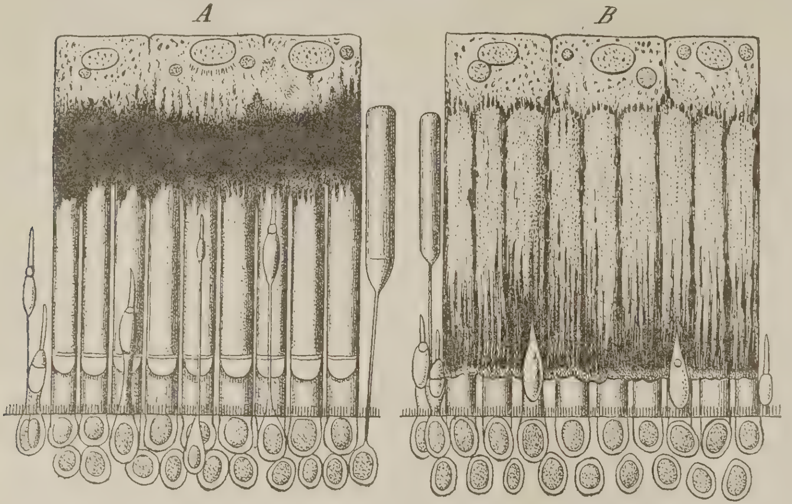


FIG. 2006.—Sections of Frog's Retina Showing the Action of Light upon the Pigment Cells, and upon the Rods and Cones. (von Gendesen—Stort). *A*, From a frog which had been kept in the dark for some hours before death; *B*, from a frog which had been exposed to light just before being killed. Three pigment cells are shown in each section. In *A* the pigment is collected toward the nucleated part of the cell, in *B* it extends nearly to the basis of the rods. In *A* the rods, outer segments, were colored red (the detached one green), in *B* they had become bleached. In *A* the cones, which in the frog are much smaller than the rods, are mostly elongated, in *B* they are all contracted.

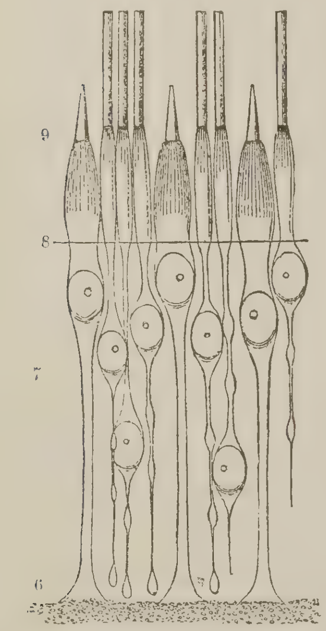


FIG. 2007.—Neuro-epithelium of the Human Retina. (Max Schultze.) 6, Arborescent processes, forming the appearance known as the "external molecular layer"; 7, nuclei of the epithelial cells, forming the "external nuclear layer"; 8, grillwork formed by processes of the fibres of Müller, forming the "membrana limitans externa"; 9, specialized processes of the epithelium, forming the layer of rods and cones.

The pigmented layer comprises the entire outer lamella of the optic cup, the part not invaginated in the course of its development, and is composed of a single layer of tesselated polygonal cells (Fig. 2005), whose protoplasm is crowded with colored granules (the fuscin of Kühne), which have the form of minute crystals with long axes perpendicular to the retinal surface. They are somewhat more deeply colored near the ora serrata. The outer surface of the cells, applied to the basilar lamina of the choroid, is smooth and devoid of pigment; the inner surface is not well defined, for it consists of fringe-like filaments loaded with pigment that extend down between the outer segments of the rods and cones which are applied directly against it. Experiments have shown that the distribution of the coloring matter in these cells varies with exposure to light, for during prolonged darkness it is withdrawn into the cell bodies, while after the stimulus of light it descends like a curtain into the fringe between the rods and cones (Fig. 2006). The visual purple found in the outer segments of the rods appears to be derived from the pigmented layer.

The neuro-epithelial layer, or layer of visual cells proper, comprises two distinct elements, the rod cells and the cone cells (Fig. 2007), set in a framework (external limiting membrane) formed by processes from the fibres of Müller, and projecting into the pigmented fringe already described. These cells are bipolar in form, having elliptical cell bodies (rod and cone granules) with large nuclei surrounded by a small amount of protoplasm from which processes extend radially in either direction. The outer one of these expands into the peculiar bacillary forms known as the rods and cones; the inner one extends inward for a short distance and ends either in a rounded knob (rod cells) or an expanded foot (cone cells) embraced by the filamentous terminals of the ganglion cells of the next layer.

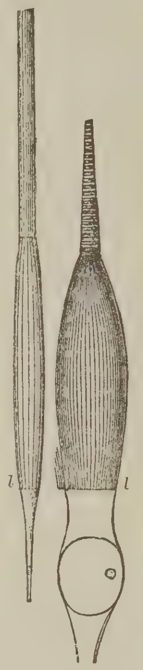


FIG. 2008.—A Rod and a Cone from the Human Retina. *l*, Situation of the membrana limitans externa.

The bodies of the rod cells, which lie at various levels, show when stained under favorable conditions dark and light bands. The rods themselves are divided into two nearly equal segments: an outer, cuticular, doubly refracting one, and an inner, protoplasmic singly refracting one; the former being cylindrical, staining but slightly and having a tendency to break up into superimposed discs; the latter slightly elliptical in outline, staining readily and showing at its outer end a fibrillated area called the ellipsoid, more apparent in the lower animals

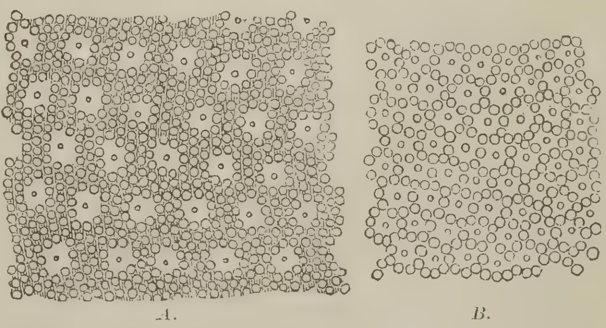

A. *B*.

FIG. 2009.—Distribution of the Rods and Cones. *A*, From the peripheral portion of the retina; *B*, from the region of the macula lutea.

than in man (Fig. 2008). The outer segments are purplish-red in tint, owing to the diffusion through them of *visual purple* or rhodopsin, the peculiar coloring matter of the retina, which quickly bleaches in the presence of light.

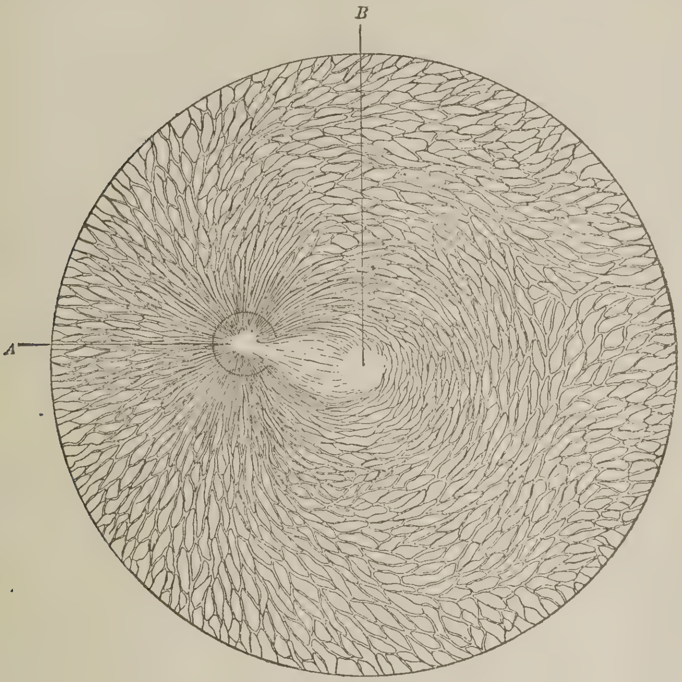


FIG. 2010.—Radiation of the Optic Nerve Fibres upon the Retina. (Michel.) *A*, Optic disc; *B*, macula lutea.

The bodies of the cone cells (Fig. 2007) are contiguous to their bacillary processes or cones. The latter also have an outer and an inner segment. The outer segment, apparently similar in intimate structure to that of the rods, is, however, much shorter, ending in a blunt point. The inner one, thick and flask-shaped, contains also an ellipsoid. During prolonged darkness the cones appear to stretch outward toward the pigmented layer (Fig. 2006). They do not contain rhodopsin.

The distribution of the rods and cones varies in different parts of the retina and in different animals (Fig. 2009). In the central fovea, the region of the most acute vision, cones only are found, but from this point forward the proportion of rods gradually increases, until at the ora serrata cones are almost wholly absent. It is estimated by Krause that there are in the retina about seven million cones, or seven to each fibre of the optic nerve, and that the number of rods is about 130,000,000. While in fishes the rods far exceed the cones in number, in birds and reptiles the reverse is the case, lizards possessing cones alone.

In the layer of bipolar cells the characteristic elements are fusiform with protoplasmic processes that surround the inner terminals of the visual cells. They may therefore be distinguished as rod bipolars and cone bipolars according as they are related to the rod or to the cone cells. The rod bipolars have protoplasmic processes with vertical arborizations, embracing from three to twenty bases of rod cells, and long axis-cylinder processes that penetrate centrally as far as the bodies of the multipolar cells, around which they ramify. The cone bipolars have protoplasmic processes, with horizontal arborizations that interblend with twigs from the feet of several cone cells, probably including also in their contact area some of the terminations of the rods. Their axis-cylinder processes are much shorter than those of the rod bipolars and terminate on five different and quite determinate levels by blending with the ascending processes of the cells of the next layer.

The layer of multipolar cells consists of large, irregularly oval elements with protoplasmic processes that intertwine with arborescences of cells from the outer layers, and whose axis-cylinder processes turn toward the optic disc and become fibres of the optic nerve (Fig. 2010). The cells of this layer are classified according to the arrangement of their protoplasmic processes: (1) monostratified, those whose processes ramify in but one level; (2) multistratified, those whose processes ramify in more than one level; (3) diffuse, those whose protoplasmic arborescences are not limited to definite levels.

At two different levels of the retina associative cells are found: (1) in relation to the rod and cone cells; (2) in relation to the layer of bipolar cells (Fig. 2011). The first class run parallel to the layers of the retina and hence are often called *horizontal* cells, three varieties of which are distinguished: one small, flattened, stellate, *cone associatives*, connecting cone-terminals with each other; another larger and placed somewhat deeper, *rod associatives*, connecting by means of long axis-cylinder processes rod terminals; a third, large, pyriform in shape, having descending processes that pass centralward as far as the internal ramifications of the bipolar cells.

The second class of associative cells is situated in the internal portion of the layer of bipolar cells, constituting there what some authors recognize as a distinct layer of the retina. W. Müller, supposing them to be of a sus-

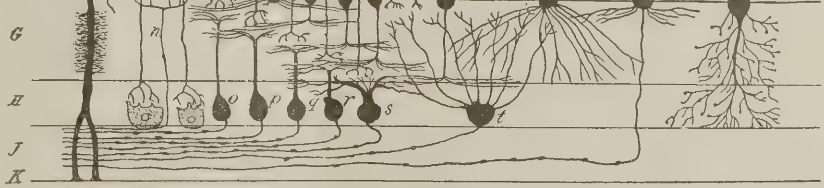


FIG. 2011.—Diagram Illustrating the Relation of the Retinal Elements. (Kallius.) *A*, Layer of rods and cones; *B*, limitans externa; *C*, outer nuclear layer (bodies of visual cells); *D*, Henle's external fibrous layer (composed principally of rod fibres); *E*, outer plexiform layer; *F*, inner nuclear layer (rod and cone bipolars); *G*, inner plexiform layer; *H*, layer of large ganglion cells; *J*, fibre layer; *K*, limitans interna; *a*, supporting fibre of Müller; *b*, *c*, rod and cone visual cells; *d*, bipolars belonging to rod cells; *e–i*, bipolars belonging to cone cells; *k–m*, horizontal nerve cells; *n*, centrifugal nerve fibre; *o–t*, ganglion cells connected with optic fibres; α–ϵ, amacrines arranged in layers; ζ–ϑ, diffuse amacrines; η, nervous amacrine.

tentacular character, called them spongioblasts. It seems desirable to discontinue the use of this name as it has been applied by His to totally different structures, the primitive cells of the medullary plate from which neuroglia is formed. Ranvier, who regarded these elements as undoubtedly nervous, designated them as unipolar cells. Cajal, having in view the fact that they do not show any axis-cylinder process of the typical form, called them *amacrine* cells, from *a*, privitive; *μακρός*, long; *ἴς*, *ἰνός*, nerve—*i.e.*, having no long process. The name is not wholly satisfactory, as homologous structures in reptiles and birds undoubtedly possess a distinct axis-cylinder process, and in man a considerable difference is noted in the ramifications on two sides of the cells.

These cells are large and pyriform with arborescent processes extending inward, and may be subdivided into *diffuse* amacrines that send ramifications throughout all levels where the terminals of the bipolars branch, and *stratiform* amacrines that confine their ramifications to one of the five levels at which the cone bipolars terminate. Their terminal filaments appear to embrace the inosculations of the bipolar and multipolar cells.

It will be remembered that the greater part of the fibres of the optic nerve originate as outgrowths from the cells of the retina. Some "centrifugal" fibres do, however, occur, probably for conveying impulses from the brain to the retinal cells (Fig. 2012). Some of these end by ramifications about the amacrine cells, others at various levels by horizontal arborescence.

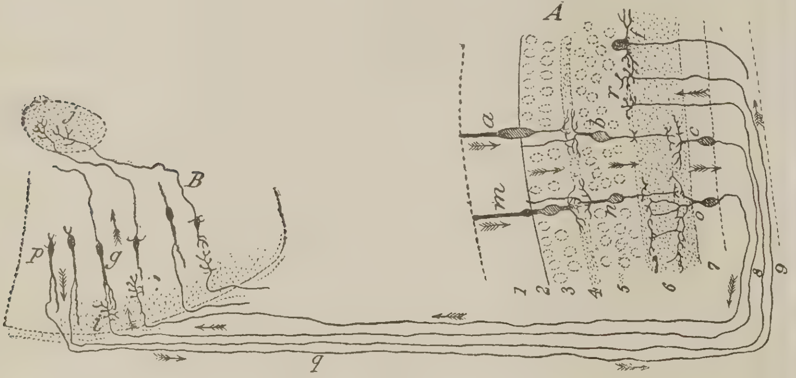


FIG. 2012.—The Course of Nerve Fibres Between Retina and Brain. (Ramon y Cajal.) *A*, Retina; *B*, corpus geniculatum; *j*, central ganglion; *a*, *b*, *c*, a cone system composed of a rod, a bipolar cell, and a multipolar cell; *m*, *n*, *o*, a rod system composed of a rod, a bipolar cell, and a multipolar cell; *g*, cells of the corpus geniculatum that receive excitations from the retina through the optic nerve; *p*, *q*, *r*, a centrifugal current originating in the brain and passing to the retina.

During the early development of the neural tube certain cells, called by His spongioblasts, become shaped into rods extending throughout the entire thickness of the wall of the tube and constituting, by interlacing processes, an efficient framework for supporting the delicate protoplasmic nerve cells that they surround. These elements remain as the neuroglia of adult nervous tissue. The retina shows its genetic relation to the medullary tube by the possession of similar sustentacular elements which are known as the *fibres of Müller* and the *spider cells.*

The fibres (Fig. 2011) extend radially throughout all portions of the percipient retina, being especially well marked near the ora serrata and in the macula lutea. They are greatly modified and elongated cells, whose nuclei lie at the level of the layer of bipolar cells. At the internal surface of the retina they commence by broad and often forked bases that unite with each other to form a continuous boundary known as the *internal limiting membrane*, which, however, cannot in any way be considered to be an independent structure. At their distal or external ends they unite to form a grillwork around the rods and cones which project beyond them. This fenestrated structure is inaptly called the *external limiting membrane.* Septa from the fibres closely invest the bodies of the visual cells, and delicate lateral processes are also given off by them for the support of the terminals of the bipolar, multipolar, and amacrine cells.

Stellate neuroglia or spider cells are found near the inner surface of the retina between the bundles of nerve fibres and among the multipolar cells.

The structure of the retina in the macula lutea and fovea centralis varies somewhat from that already described (Fig. 2013). In the fovea the cones are the only visual cells found, being there much narrower and longer than in other regions. The conical depression of the fovea causes the fibres of the cells to be drawn out obliquely. The bipolar and multipolar layers disappear at the centre of the fovea, but immediately about it, within the macula, become increased in thickness.

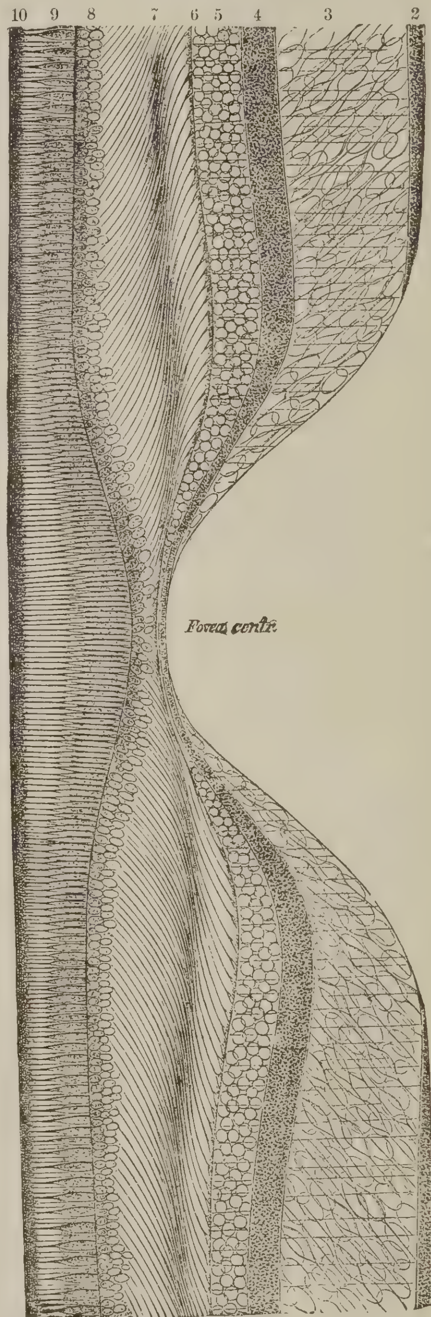


FIG. 2013.—Diagrammatic Section of the Macula Lutea and Fovea Centralis. 2, Layer of nerve fibres; 3, layer of multipolar cells; 4, internal molecular layer, composed of intertwining arborescent processes; 5, layer of bipolar cells, or internal granular layer; 6, external molecular layer, composed of intertwining arborescent processes; 7, nuclei of epithelial cells, or external granular layer; 8, frillwork formed by processes from fibres of Müller, often called the "external limiting membrane"; 9, layer of rods and cones; 10, layer of pigment epithelium.

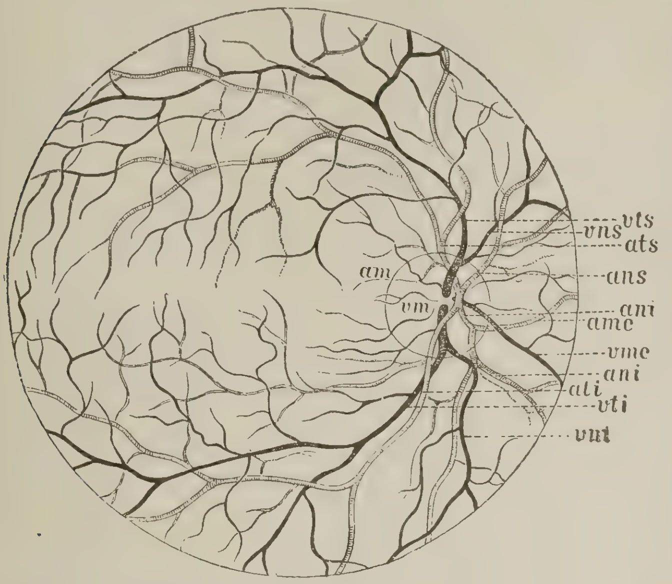


FIG. 2014.—Diagram of the Blood-vessels of the Human Retina. (Leber, after Jaeger.) *ans*, *vns*, Superior nasal artery and vein; *ats*, *vts*, superior temporal artery and vein; *ani*, *vni*, inferior nasal artery and vein; *ati*, *vti*, inferior temporal artery and vein; *am*, *vm*, macular artery and vein; *ane*, *vme*, median artery and vein.

The Ciliary Retina.—As we approach the ciliary region the highly specialized structures that characterize the fundus of the retina become changed. The cones become more scanty, the multipolar cells are fewer, the rods are shortened and disappear. Finally the elements are abruptly reduced to a simple layer of columnar epithelium. This sudden diminution leaves a line of demarcation known as the ora serrata, well seen by the unassisted eye.

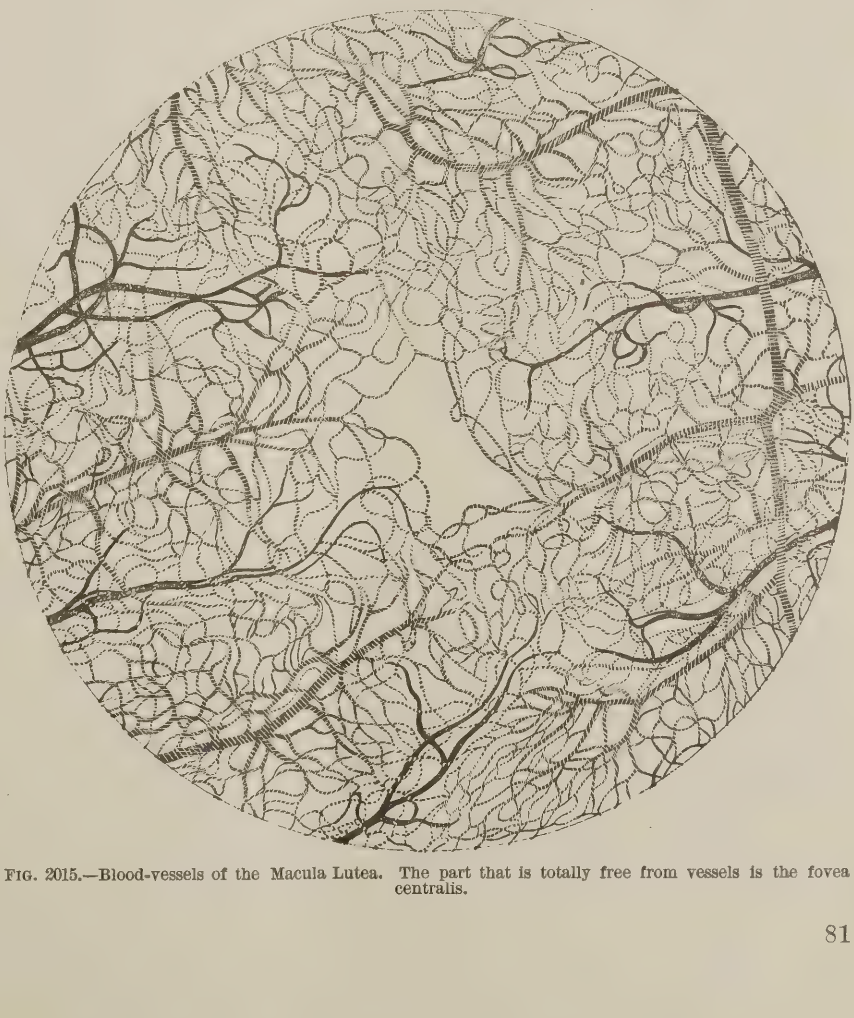


FIG. 2015.—Blood-vessels of the Macula Lutea. The part that is totally free from vessels is the fovea centralis.

The retinal blood-vessels (Fig. 2014) are derived from the central artery of the retina, which, as already stated, pierces the nerve at from 15 to 20 mm. behind the eyeball and appears on the disc at the bottom of the excavation. It immediately breaks up into two branches, the *superior* and *inferior papillary arteries*, each of which subdivides into a temporal and a nasal branch. The papular arteries also send small twigs, the *macular arteries*, toward the region of the yellow spot. Except at the optic-nerve entrance, where a capillary anastomosis occurs with twigs from the posterior ciliary arteries, all these vessels form a system independent of that of the choroid. They ramify mainly in the layer of multipolar cells and do not anastomose with each other. At the central fovea the vessels from this system are wanting (Fig. 2015), as might be expected from the absence of the inner layers at that place.

The *crystalline lens* (Figs. 2016, 2017, 2018), is a transparent biconvex body with a circular margin, applied to the opening of the pupil, touching the iris in front and resting behind in a shallow depression of the vitreous, known as the *hyaloid fossa.* Its margin is from 0.5 to 0.6 mm. from the ciliary processes to which it is united by a suspensory ligament called the *zonula.* Its diameter is from 9 to 10 mm., and, having the unique property of changing its form under the influence of the ciliary muscle for adaptation to vision of near or remote objects, its thickness varies from 3.7 to 4 mm. While not mathematically exact, its curved surfaces are nearly those of spheres, the radius of the anterior one varying from 10 to 6 mm., that of the posterior one from 6 to 5 mm., according as the lens is accommodated for distant or near objects. The fœtal lens is nearly circular; in old age it becomes flattened.

The weight of the adult lens is from 0.20 to 0.25 gm., specific gravity 1.121, volume 0.25 c.c. The central core or *nucleus* is more condensed and less elastic than the peripheral part or *cortical substance,* though its histological structure is the same. This difference does not exist in the fœtus and increases with age, depriving the lens of its elasticity, so that the eyes of elderly persons do not readily accommodate for distance. The nucleus refracts more than the cortical substance, the indices being 1.4541 and 1.4053 respectively, that of distilled water being

1.3342 (Krause). The lens is completely enveloped by a structureless elastic capsule thicker in front than behind, which resembles in its reactions the sarcolemma of muscle or the membrana propria of glands.

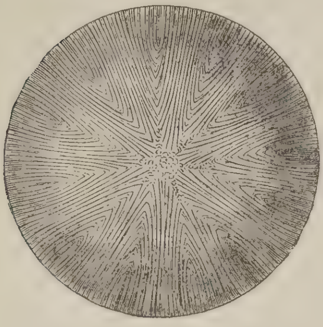


FIG. 2016.—Anterior Surface of Adult Lens. (Arnold.)

The development of the lens is the key to its structure. It will be remembered that it is formed from an invagination of the external epithelium that becomes isolated as the lenticular vesicle and that the cells of the anterior wall retain their epithelial characters, becoming more and more columnar toward the margin or equator of the lens, while those on the retinal aspect become lengthened into flattened fibres that vary in size and length in the central and the peripheral portions (Fig. 2019). The superficial fibres are from 0.010 to 0.012 mm. wide, 0.005 mm. thick, and 8 mm. long, while those of the deeper portion are 0.0075 wide, 0.0025 thick, and 4 mm. long. In the middle and interior portions of the lens the edges of the fibres are finely serrated (Figs. 2020, 2021), but these serrations do not fit into each other and there are thus left between the fibres fine spaces that serve for the passage of lymph. As the lens has no blood-vessels such a provision seems necessary for its nutrition. Between the epithelium and the lens fibres is the original cavity of the lenticular vesicle reduced to a narrow slit filled with semifluid material. This rapidly liquefies after death and becomes the so-called *liquor Morgagni.*

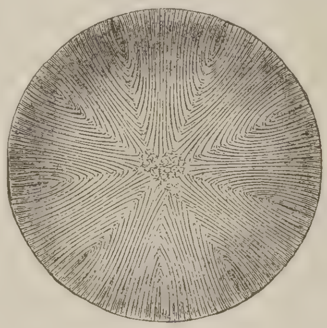


FIG. 2017.—Posterior Surface of Adult Lens. (Arnold.)

When treated by appropriate reagents the fibres of the peripheral third of the lens may be separated into concentric layers like those of an onion (Fig. 2022). In each layer the fibres have approximately the same length and terminate along nearly regular radiating lines called the *lens stars* (Fig. 2023). In the young lens these have behind an arrangement like a Y, in front that of the same letter reversed (⅄). They are more complicated in the adult.

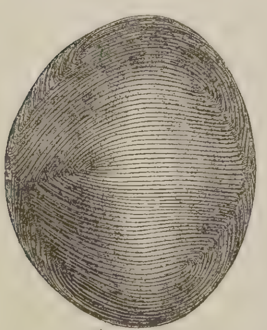


FIG. 2018.—Lens of a Child at Birth Seen from the Side. (Arnold.)

The *zonula,* formerly thought to consist of two folds of a tenuous membrane enclosing a triangular canal (canal of Petit) that encircles the lens, is now known to be a system of delicate fibrillæ that extend from the ciliary region and the hyaloid membrane to be implanted upon the capsule of the lens. The origin and exact nature of these fibrillæ is still under discussion. It seems probable that they originate like the vitreous from mesenchymal connective tissue. They form an annular structure about 6 mm. wide that completely encircles the lens, serves to hold it in position and to keep the capsule tense.

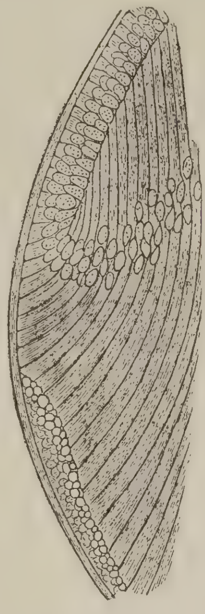


FIG. 2019.—Meridional Section Through Lens of Calf. (Arnold.)

The anterior chamber has the character of a lymph space developed in the connective tissue that primitively separates the lens from the external epithelium. This cavity is filled by the *aqueous humor,* a sparkling, transparent fluid containing 98.71 per cent. of water and having a considerable similarity to lymph. The quantity of this is from 231 to 323 c.mm. and remains nearly constant during life, being sufficient to maintain an intraocular tension equal to that of a column of mercury 26 mm. in height. Its specific gravity is 1.0053 and its index of refraction 1.3420, that of distilled water being 1.3342 (Krause). Apparently it is constantly renewed by a secretion from the vessels of the choroid, particularly those of the ciliary processes, and removed from the chamber by infiltration through the spaces of Fontana into the scleral sinus and perhaps by the lymph crypts of the iris. Normally it contains no morphological elements.

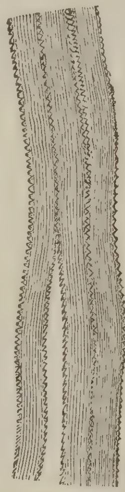


FIG. 2020.—Isolated Fibres from Lens. (Arnold.)

Behind the lens the cavity of the eyeball is filled with the *vitreous humor* or *body,* a transparent, jelly-like material that has the characters of a primitive form of very watery connective tissue, showing widely scattered cells embedded in a matrix of gelatinous material in which appropriate reagents develop a rich fibrillary network. Leucocytes are also found in it, especially where it is in contact with the retina. It has a very delicate envelope, the *hyaloid membrane,* adherent to the retina at the optic disc and the ciliary region where arteries enter during fœtal life. This membrane does not pass down into the intervals between the ciliary bodies, but spans them over, forming thus small meridional spaces, the *recesses of the posterior chamber,* which are filled with aqueous humor infiltrated through the zonula from the anterior chamber. In front the vitreous has a depression, the *hyaloid* or *patellar fossa,* into which the lens is received. The hyaloid membrane appears to be lost upon the zonula in front and not to

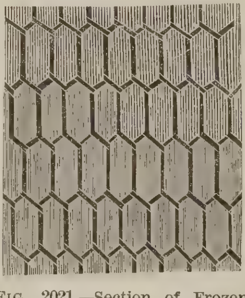


FIG. 2021.—Section of Frozen Lens Showing Hexagonal Shape of Fibres. (Arnold.)

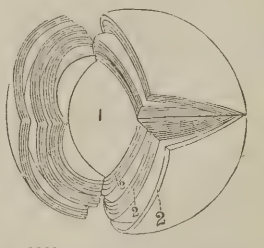


FIG. 2022.—Lamination of the Lens as Shown After Treatment with Dilute Alcohol. (Arnold.) 1, Former central portion called the nucleus lentis; 2, 2, layers of the so-called cortical substance.

be continued over the hyaloid fossa, the consistence of the vitreous at that place being maintained by a condensation of its substance. From the optic disc forward there runs in fœtal life a small vessel, the *hyaloid artery,*

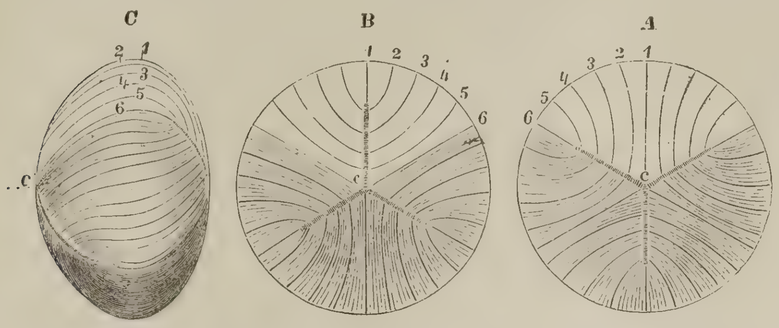


FIG. 2023.—Arrangement of the Fibres of the Lens in the Fœtus and at Birth. *A*, Posterior surface; *B*, anterior surface; *C*, side; *c*, centre of the lens stars, being the anterior and posterior poles of the lens; 1 to 6, course of fibres taken at equal distances.

for the nourishment of the lens. This is represented in the adult by a central lymph space, the *hyaloid canal* (Fig. 1952). Just in front of the disc this canal enlarges to a space known as the *area Martegiani.*

The refractive index of the vitreous body is nearly that of distilled water, its weight is from 6.7 to 8.3 gm. and its specific gravity is 1.005. Its reaction is alkaline, and the proportion of water found in it is very high, being 98.40 to 98.64 per cent. *Frank Baker.*

EYE, DIOPTRICS OF.—REFRACTION.—1. The term refraction refers in physics to the deviation of a ray of light from its straight path on passing from one transparent medium into another of different nature. In physiological optics, however, this term is used with a special significance, denoting the relation of the focal length of the eye to the position of the retina. The eye has a normal, or emmetropic (from ἔμμετρος, according to measure, and ὤψ, eye), refraction, if images of distant objects are sharply defined on the retina; the refraction is myopic, or near-sighted, if distant objects form images in front of the retina; while hypermetropia is that refractive state in which images of distant objects can be sharply defined only behind the actual place of the retina. Any refractive state other than emmetropia is referred to in general as ametropia (from ἄμετρος, disproportionate, and ὤψ, eye).

The eye of all vertebrates is an optic instrument, the principle of which is illustrated by the photographer's camera obscura. By means of a convex lens, the rays of light coming from the different points of external objects are so reunited as to form inverted, but geometrically correct, images of those objects on a screen. The screen is the retina, while the convex lens is constituted by all the transparent media of the eyeball.

A correct knowledge of the optic properties of the eye is not possible without some familiarity with the laws of physical dioptrics. Hence we must begin with a résumé of the laws of the refraction of light. In order to keep this article within the allotted space, we will not attempt to follow out the mathematical deduction of all the various formulæ of which we must make use. For the complete mathematical proof of all the statements the reader must consult some of the works mentioned in the bibliography, especially those of Helmholtz and Donders.

The paths of the rays of light entering the eye, and the influence of the different media upon them, can be deduced from the following optic principles:

2. *Law of Refraction.*—From every point of a luminous or illuminated object there proceed rays of light in all directions. Every ray pursues a straight course as long as it passes through a uniform medium. When a ray passes from one transparent medium into another of different optic properties, it is refracted or deflected from its straight path, except when its original direction is vertical to the surface of the second medium. The extent of deflection depends on a specific property of each medium, viz., its refractive power. The relation of the refractive power of any one medium to that of another is termed the refractive index, and is usually designated by the letter n. Air is taken as the standard of comparison, and its index of refraction is called 1. Compared with air the refractive index of water is 1.334; of crown glass, 1.533; of flint glass, 1.664. A medium having the greater refractive index is said—in a somewhat loose manner—to have a greater optic density than another rarer medium.

The extent to which a ray of light is deflected from its straight path, by refraction, depends on the angle at which it strikes the surface, as well as on the refractive indices of the media.

Let A, in Fig. 2024, be air, with the refractive index $= n$, and B be glass, with the index $= n'$, the two being separated by the surface $s\,s'$. A ray of light, having the direction $a\,c$ in the air, will be bent in the direction $c\,d$ on entering the glass. If we erect the normal $b\,c\,e$ vertical to the surface at the point c, the angle $a\,c\,b$ is the angle of incidence of the ray $a\,c$; the angle $e\,c\,d$ is the angle of refraction. The latter is here smaller than the former, for, in the denser medium, the refracted ray is bent toward the perpendicular. The relation of one angle to the other depends on the relation of the refractive indices of the two media, so that the sine of either angle is to the sine of the other inversely as the index of the corresponding medium is to that of the other, or

$$\frac{\text{sine } a\,c\,b}{\text{sine } e\,c\,d} = \frac{n'}{n} \tag{1}$$

Since the sine of an angle zero is likewise zero in value, it follows that when the incident ray is itself perpendicular to the refracting surface, it continues to be perpendicular after its entrance into the second medium, *i.e.*, it is not deflected at all from its course.

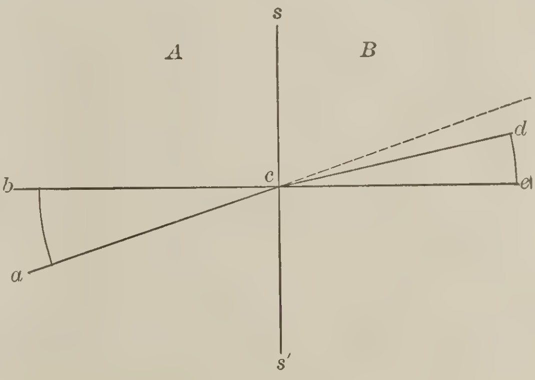


FIG. 2024.

The path which a ray describes in passing through one or more refracting surfaces is the same, whether that ray travels forward or backward from any given point in its course.

3. If the denser medium is in the form of a plate bounded by parallel surfaces and surrounded by the same rarer medium on both sides, a ray, after passing through the plate, follows a direction parallel to its original course, but is displaced laterally.

For in Fig. 2025, where *A* represents the air, and *B* the plate of glass, the ray *a c* on entering the glass is bent toward the perpendicular *d c* to an extent exactly counterbalanced by its deflection from the perpendicular *e f* on leaving the glass. Hence the ray *e b* after passing through the glass is parallel to the prolonged direction of the original ray *a c*.

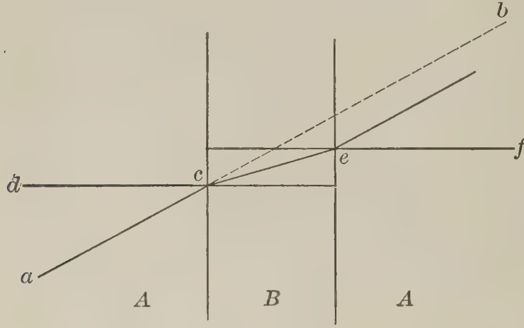


FIG. 2025.

4. *Refraction by a Single Refracting Surface.*—When the denser medium is bounded by a convex spherical surface, all rays (except one) coming from any point in the rarer medium are deflected in such a manner as to be less divergent after their refraction than they were before. The one ray not deflected is the one striking the surface vertically, hence coinciding in the radius or axis of that point of the surface. It is hence termed the *axial ray*.

In Fig. 2026 let *a* be a point in the air from which rays proceed toward the convex surface *b c* separating the air from the glass. Let *o* be the centre of curvature of the refracting surface *b c*. Let the ray *a c* be vertical to the surface, *i.e.*, coinciding with the direction of the radius *o c;* it will hence not be deflected from its course. The ray *a b* is, however, refracted. If *o b* is the radius of the surface, and is hence vertical to the point *b*, the angle of refraction *f b o* can be found by the formula:

$$\text{sine } f\,b\,o \;:\; \text{sine } a\,b\,d = n \;:\; n'$$

It is evident from Fig. 2026, that if the point *a* be not too near to the refracting surface, the refracted ray *b f* will verge toward the undeflected axial ray, and will meet it in some point which we will designate *f*. It can be shown by a mathematical analysis, that not only this one ray, but that all rays proceeding from the point *a* toward the convex surface *b c* are so refracted as to meet the axial ray at the point *f*, provided we limit our analysis to those rays only which are not very oblique to the axis, and do not strike the surface far from the axis. With this provision, the point *f* is the collecting point of all rays coming from *a;* the point *f* is therefore the image of the point *a*. If we trace, however, the course of the rays which are very oblique to the axial ray, or which strike the surface far from its axis, we shall find that they meet the axial ray at various points different from *f*. Such a want of exact reunion of all the rays, when too large an extent of the refracting surface is exposed, constitutes the fault of optic instruments known as *spherical aberration*. The refraction of such very oblique rays is represented, in a somewhat exaggerated manner, in Fig. 2027.

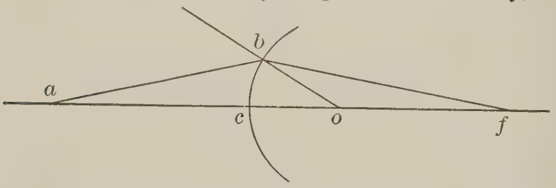


FIG. 2026.

5. *Focal Length.*—When the luminous point is situated in the rarer medium at a distance infinitely great compared with the dimensions of the refracting surface, the different rays emanating from that point strike the refracting surface with so little divergence as to be practically parallel to each other. These parallel rays are rendered convergent by their refraction. The point where these refracted rays meet is called the principal posterior focus, and its distance from the refracting surface is the posterior focal length. This distance, designated usually as F'', depends on the relative indices of refraction of the first and second media and on the radius of curvature of the refracting surface. If we call this radius r, the formula for the posterior focal length is:

$$F'' = \frac{n'\,r}{n' - n} \qquad (2)$$

The plane drawn through the posterior focus vertical to the axis of the refracting surface is called the posterior focal plane.

As the luminous point moves nearer to the refracting surface, so as to make the incident rays more and more divergent, their focal reunion recedes farther from the surface, until a certain point in front of the convex surface is reached, the rays proceeding from which are so divergent that they can no longer be rendered convergent by their refraction, but only parallel. Their point of focal reunion may then be considered as infinitely far behind the surface. The point in front of the surface from which these rays proceed is the principal anterior focus, and its distance from the surface, which we will call F', is the anterior focal length. A vertical plane laid through it is the anterior focal plane. F' can be found by the formula:

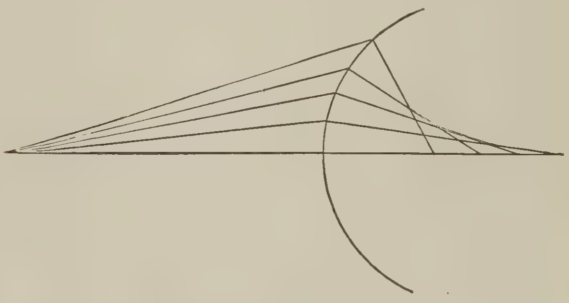


FIG. 2027.

$$F' = \frac{n\,r}{n' - n} \qquad (2a)$$

A comparison of formulæ (2) and (2a) shows that the anterior and posterior focal lengths are not alike under the circumstances, but that

$$F' : F'' = n : n' \qquad (2b)$$

Remembering that the path of the rays is the same, whether they travel forward or backward, we may also define the anterior focus as the point in which rays unite, which proceed parallel to each other in the denser medium toward the refracting surface.

6. The distance of the focal reunion from the refracting surface can be calculated for any set of rays, coming from any point, if we know the distance of that point from the surface, and also the anterior and posterior focal lengths of the refracting surface. If f' be the known distance of the luminous point, the distance of the corresponding focal reunion f'' will be:

$$f'' = \frac{F''\,f'}{f' - F'} \qquad (3)$$

Conversely, the distance of a luminous point f' can be found, if we know the distance of its corresponding focal reunion or image f'', according to the formula:

$$f' = \frac{F'\,f''}{f'' - F''} \qquad (3a)$$

A very convenient formula for finding the place of the focal reunion of rays coming from a point at a known distance can be obtained by the transformation of (3) and (3a). If we designate the distance from the luminous point to the anterior focus, viz.: $f' - F'$ as l' (counting l' negative if f' is nearer to the surface than F'), and the distance from the posterior focus to the point of focal reunion of the rays in question, viz.: $f'' - F''$ as l'', then

$$l' \, l'' = F' \, F'' \tag{3b}$$

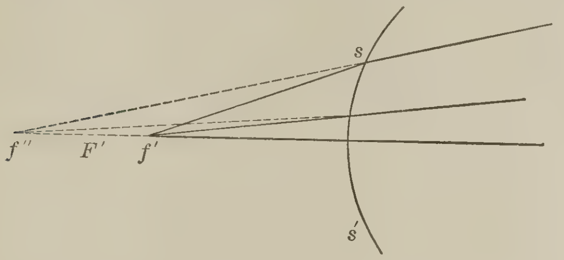


FIG. 2028.

In all these instances the relation of luminous point and corresponding image can be reversed without change of position; in other words, if the point x is the image of the point a, then for rays proceeding in the reverse direction, a is also the image of the point x. Any two points having such a relation of luminous point and corresponding image are called *conjugate points.*

7. *Virtual Image.*—When the rays, coming from a point nearer than the anterior focus, strike the refracting surface, their divergence is too great to be entirely overcome by the refraction. They cannot therefore be united to form an actual image; but if their direction, after the refraction, be prolonged backward, their prolongations meet to form a *virtual* image. The focal reunion of such rays is therefore negative.

Thus, in Fig. 2028, if F' be the principal anterior focus of the refracting surface $s\,s'$, and f' the luminous point, the rays proceeding from f' will have a divergence after their refraction, as if they came from the point f'', which is therefore the image of f'. Since f'' is on the same side of the surface as f', its distance is counted negative. It can be determined by formula (3a) or (3b).

8. *Formation of Images.*—Since an object is made up of an infinitely great number of points, and since of every such point in front of the refracting surface an image is formed somewhere behind the surface, therefore an image must also be formed of the entire object. From every point of the object there proceeds one ray, which is not bent from its course by refraction, viz.: the ray which strikes the surface perpendicularly, and hence coincides in direction with the radius of the point of the surface. Such rays are termed *rays of direction.* Since all other rays proceeding from any one point of the object meet the ray of direction at the corresponding distance of focal reunion, the image of every point of the object is situated somewhere in the path of the ray of direction coming from that point. Since every ray of direction coincides with one of the radii of the refracting surface, the rays of direction must, therefore, like the radii, intersect at the centre of curvature of the surface. Since the focal length of a refracting surface is always greater than its radius, according to formulæ (2) to (3a), therefore the actual images of objects farther off than the anterior focus are formed somewhere beyond the point of intersection of the rays of direction, and are hence inverted. This is illustrated by Fig. 2029.

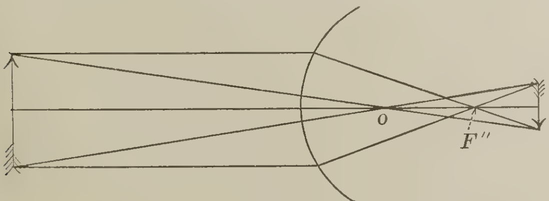


FIG. 2029.

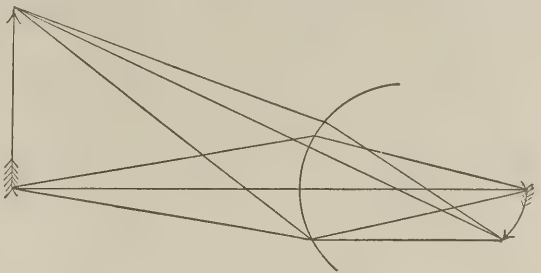


FIG. 2030.

The point where the rays of direction cross, viz.: the centre of curvature of the surface, is also called the *optic centre.*

9. When the object lies in a plane vertical to the axis of the refracting surface, all points of the object near the axis are sensibly at the same distance from the refracting surface, as measured by the length of the rays of direction. Their images are therefore likewise situated at equal distances behind the surface, and hence lie in a plane vertical to the axis. But this is true only as long as the angle included between the ray of direction coming from that point of the object, and the axis of the refracting surface is so small as to permit the substitution of its chord for its arc without practical error. In the case of objects of dimensions exceeding this limit, the images lie in a curved line, with the concavity toward the refracting surface, as shown in Fig. 2030.

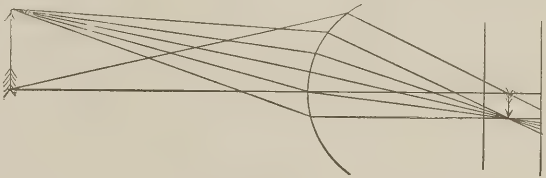


FIG. 2031.

Such extensive images are blurred, on account of spherical aberration. (See Section 4.)

10. *Circles of Diffusion.*—An image is sharply defined only in the plane of focal reunion of the rays. In any plane anterior to this the rays are not yet united; in any plane posterior to this the rays diverge again. Hence a screen placed in front or in the rear of the focal reunion receives a blurred image, since every point of the object is represented—not by a single point—but by a circle of diffusion. The size of the circles of diffusion increases with the distance of the screen from the point of focal reunion in either direction, and with the extent of the refracting surface through which rays pass. This is evident from Fig. 2031.

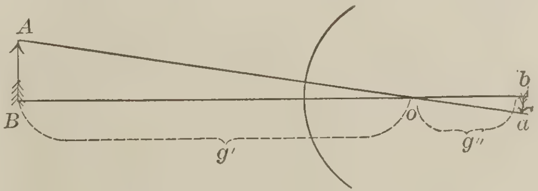


FIG. 2032.

11. *Size of Images.*—The size of the image is to the size of the object as the distance of the image from the optic centre is to the distance of the object from the same point. If we designate, in Fig. 2032, the distance of the

object AB from o, the optic centre, as g', and the distance of the image ab from o as g'', we can express the relation of size by the formula:

$$ab : AB = g'' : g' \qquad (4)$$

the truth of which is evident from the similarity of the two triangles ABo and abo. For certain calculations the relation of size can be more conveniently stated as

$$ab : AB = f'' - F'' : F'' \qquad (4a)$$

in which formula F'' is the principal posterior focal length, and f'' the distance of the image from the surface. The derivation of this formula is shown in Fig. 2033.

For if we draw in this figure the ray Ad from the point A parallel to the axis, it is refracted as if it were a ray coming from some point in the axis at an infinite distance, that is to say, it is deflected to F'' the posterior focus, and proceeds beyond F'' until it meets the other rays coming from A in the point of focal reunion a. Thereby are formed the two similar triangles dcF'' and abF''. Hence,

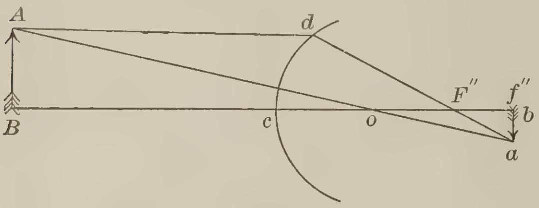


FIG. 2033.

$$ab : dc = f''F'' : cF''$$

Since the line Ad has been drawn parallel to Bc, the side dc is equal in size to the object AB. If we substitute the term F'' for the line cF'', and the term $f'' - F''$ for the line $f''F''$ according to our premises we get the equation:

$$ab : AB = f'' - F'' : F''$$

12. *Virtual Images.*—When the object is nearer to the refracting surface than the principal anterior focus, there is no real image, but only a virtual image is formed on the same side of the surface as the object is itself. In this case f'' is hence negative, otherwise the same formulæ apply as above. Since the rays of direction do not cross, this virtual image is erect, and since it is always farther from the optic centre than the object, it is larger than the object. The amplification of the image diminishes as the object approaches the refracting surface, for when the object has just passed through the anterior focus the image is at an infinitely great distance, and is therefore most enlarged, while when the object touches the refracting surface, object and image coincide in position and size. The formation of virtual images is shown in Fig. 2034.

13. All the facts above stated with reference to images formed in the denser medium of objects situated in front of the refracting surface, are equally true conversely of images formed in the rarer medium of objects situated behind the refracting surface.

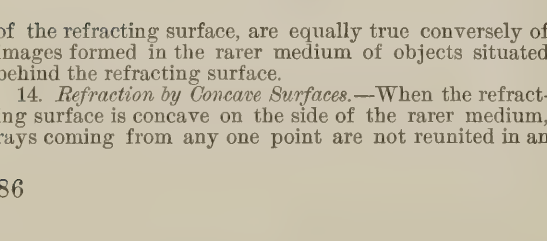


FIG. 2034.

14. *Refraction by Concave Surfaces.*—When the refracting surface is concave on the side of the rarer medium, rays coming from any one point are not reunited in an actual focus. But if the direction which they assume after their refraction be prolonged backward, the prolonged rays will meet in a point representing the focus. This focal length is therefore always negative, that is to say, the focus is always on the same side of the surface as the object itself. The position of the principal foci or any conjugate point of focal reunion can be found by the same formulæ as in the case of a convex surface, but these values are always negative, because the radius of curvature of the concave surface is negative in direction. The images formed by a concave refracting surface are hence always on the same side as the object, that is to say, they are not real, but virtual, and can only be smaller than the object, as is shown in Fig. 2035.

15. *Refraction by Successive Surfaces.* — When light passes through a number of surfaces of different media, the above-developed formulæ apply to the refraction through each surface. Thus the focus of the first surface forms the luminous point for the second refraction, its distance being counted positive when it is in front of the second surface, and negative when it happens to be behind that surface. Similarly the image formed by the second surface is the object for the third surface, and so on. But such calculations become very cumbersome if we try to follow actually the course of the rays through their successive refractions. The matter is simplified by treating the series of surfaces as one system having certain fixed points, the position of which determines the path of all rays. These are called the cardinal points. Their position remains constant in any given system, and can be calculated, if the refractive indices of the media, the radii of curvature of all the surfaces, and the distances of all the surfaces from each other are known, provided the centres of curvature of all the surfaces lie in a straight line, the axis of the system. If the latter condition is fulfilled, the system is said to be centred. The cardinal points are the two foci, the two principal points and the two nodal points.

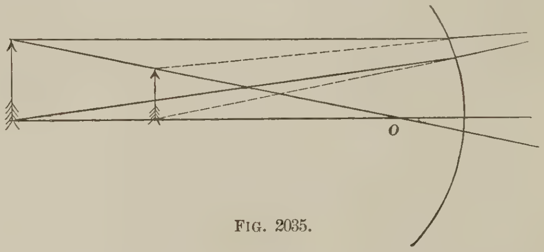


FIG. 2035.

16. *The Foci.*—The foci, anterior or first, and posterior or second, are the two points—one on either side of the system—at such distances that rays coming from the focus are rendered parallel to each other by their last refraction. Conversely parallel rays, entering the system from either side, are united in a point in the focus on the other side, as has been shown to occur in the case of a single refracting surface. The distance of either one of the foci of a compound system from the surface next to it may be computed in the following manner: Let n be the refractive index of the first medium, n_1 of the second, n_2 of the third, and so on. Let S_1 be the first refracting surface, and r_1 its radius of curvature; S_2 the second surface, and r_2 its radius, and so on. The value of r is positive if the surface is convex on the side of the luminous point; negative if it is concave. Let d_1 be the distance from the first surface to the second, d_2 from the second to the third, and so on. Determine the foci of each surface by itself, without reference to the other surfaces. According to formulæ (2) and (2a), we get for the first surface,

$$F_1' = \frac{nr_1}{n_1 - n} \text{ and } F_1'' = \frac{n_1 r_1}{n_1 - n}$$

and for the second surface,

$$F_2' = \frac{n_1 r_2}{n_2 - n_1} \text{ and } F_2'' = \frac{n_2 r_2}{n_2 - n_1}$$

The posterior focus for the first and second surfaces taken together will now be found by considering F_1'' as the luminous point for S_2; and, on applying the formula (3), viz., $f'' = \frac{F'' f'}{f' - F'}$ we get the equation:

$$F(_1 + _2)'' = \frac{F_2'' \; (d' - F_1'')}{(d' - F_1'') - F_2'} \qquad (5)$$

which states the distance of the posterior focus of the system of surfaces S_1 and S_2 from S_2 The distance of the anterior focus of S_1 and S_2 together, from S_1, is similarly found by the application of formula (3a), viz., $f' = \frac{F' f''}{f' - F''}$ and following the light in the reverse direction, hence

$$F(_1 + _2)' = \frac{F_1' \; (d_1 - F_2')}{(d_1 - F_2') - F_1''} \qquad (5a)$$

By treating the surfaces S_1 and S_2 as one system, we can then proceed to determine the foci for $S(_1 + _2)$ and S_3, and so on.

The foci of an optic system having been determined, the focal length is now measured by the distance of each focus from its corresponding principal point. If we call the anterior or first principal point H', and the posterior or second principal point H'', then F' H' is the anterior focal length, and H'' F'' is the posterior focal length.

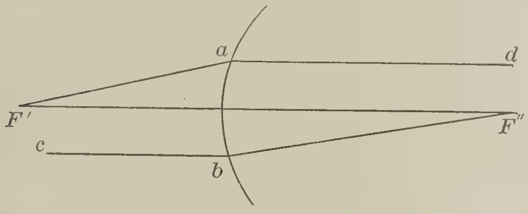


FIG. 2036.

17. *The Principal Points.*—The principal points are the two points where the axis of the system is cut by the two principal planes. The significance of the principal planes can be best explained on comparing the refraction by a single surface with the course of rays through a compound system. In the case of the single surface *a b*, Fig. 2036, the ray *F' a*, coming from the anterior focus, is, by its refraction, made parallel to the axial ray *F' F''*. Incident and refracted rays intersect here in the plane of the refracting surface. The same is true of the ray *F'' b* coming from the posterior focus, and its continuation, *b c*, after refraction. In Fig. 2037, however, where there are two refracting surfaces, *a b* and *a' b'*, the ray, *F' a*, coming from the anterior focus, is twice bent from its course, viz., at each surface, so as to finally assume the direction *a' d*, parallel to the axial ray. In this case the incident ray, *F'' a*, and the refracted ray, *a' d*, do not intersect, being separated by the space between *a* and *a'*; but if we prolong them through this space, their prolongations intersect at the point *h'*. A plane, *h' H'*, laid through this point, vertical to the axis, is the first principal plane. Similarly, if we prolong the ray *F'' b'*, which proceeds from the posterior focus to the surface *a' b'*, it will cut the backward prolongation of the refracted ray *b c* at the point *h''*, which point determines the position of the second principal plane. It is evident, from Fig. 2037, that the ray which before entering the system is directed toward the point *h'* in the first principal plane, has a direction after its last refraction as if it came from a point in the second principal plane at the same distance from the axis as the point *h'*. Likewise the ray which proceeds in the opposite direction from *F''* toward the point *h''* has a direction, after its last refraction, as if it came from a point in the first principal plane at the same distance from the axis as the point *h''*. This mutual relation of the two principal planes is the same for all rays, not merely those coming from *F'* or *F''*; and it is true also for any distance at which the points *h'* and *h''* may be from the axis within the limitations of Section 4. In other words, any ray which is directed toward a given point in the principal plane on the side from which it comes, apparently emerges from the other principal plane at the same distance from the axis. We can thus determine by construction the direction of any ray after its refraction through a compound system, and thereby find the places of the image formed by such rays, if we know the position of the foci and the two principal planes. In Fig. 2038, let *a a'* be the first, and *X X'* be the last refracting surface of a compound system; let *H'* be the first, and *H''* be the second principal point, *F'* the anterior, and *F''* the posterior focus. Draw the axis *F' F''*. From the point *B* there proceeds the ray *B a*, parallel to the axis, and verging toward the point *m'* in the first principal plane. Hence, after its last refraction, that ray has a direction as if it came from the point *m''* in the second principal plane, going through the posterior focus *F''*. Another ray convenient to follow is the one coming from *B* and passing through *F'*. This verges toward the point *n'* in the first principal plane. Hence, by its refraction, it is turned in the direction *n'' b*, as if coming from *n''* and proceeding parallel to the axis. Where the two refracted rays meet, at the point *b*, is the image of the luminous point *B*.

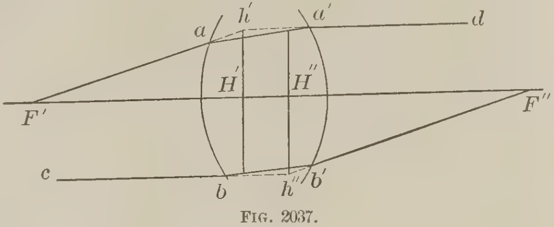


FIG. 2037.

Since the course of rays is determined by their relation to these imaginary principal planes, the focal lengths of a system must be measured by the distance of each focus from its corresponding principal point, and not by the distance of the foci from the refracting surfaces. Indeed, for all subsequent purposes, we can practically ignore the position of the refracting surfaces of any system, after we have once determined the position of the foci and of the principal planes. For now all the problems relative to the position of object and image can be solved by the same formulæ as in the case of a single refracting surface, by measuring the focal lengths from the principal planes.

18. The position of the two principal points is determined by the position of the two planes in which the images of a certain other plane are of equal size and direction. In every refracting system there exist only two such planes, and these are the principal planes; and there exists, moreover, only one plane of which two images of equal size and direction are possible. Hence, in order to find the principal points, we must determine where a line must be in order to form two images of the same size and direction, and then learn the place of these two images.

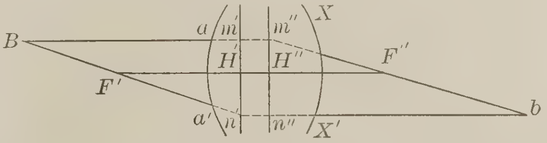


FIG. 2038.

This proposition can be demonstrated by means of Fig. 2039, in which we have a refracting system bounded by the surfaces *s' S'* and *s'' S''*. *F'* is the first and *F''* the second focus. Draw the ray *F' c*, which is deflected toward *s''* by the surface *s' S'*, and is made parallel to the axis by the surface $s'' S''$. By the intersection of the prolonged incident and refracted rays the point h' determines the position of the first principal plane. Similarly a reverse ray going from F'' to e is bent twice, so as to follow ultimately the direction $s' b$ parallel to the axis. The prolongations of the ray before entering and after leaving the system give us the point h'', and thereby the position of the second principal plane. If we draw a line $d d'$ vertical to the axis from the point d, where the rays coming from each side intersect after their first refraction, the virtual image of $d d'$ produced by the surface $s' S'$ coincides with the first principal plane $h' H'$, while the image formed by the surface $s'' S''$ coincides with the second principal plane $h'' H''$, as is evident from the refraction of the rays according to the construction; and these two images are alike in size. The distance of d' from each surface is determined by the equation (4a).

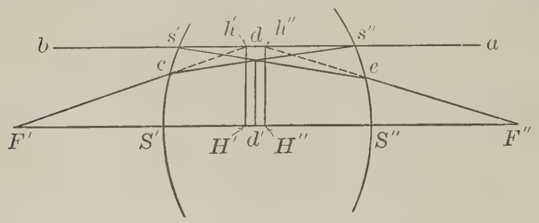


FIG. 2039.

$$a\, b\ (\textit{image}) : A\, B\ (\textit{object}) = f'' - F'' : F''$$

or more conveniently, on account of the erect position of the virtual image,

$$a\, b : A\, B = F'' - f'' : F''$$

Each surface is here considered independently of the other. Hence it can be deduced that the distances of d' from each surface must be to each other as the focal lengths of the surfaces, in order to have the images formed by the two surfaces of equal size. This is shown in Fig. 2040, where $P' S''$ is the focal length of the surface $s'' S''$ in the medium between the two surfaces and $P'' S'$ of the surface $s' S'$.

A consideration of the two triangles $P' S'' s''$ and $P'' S' s'$ and their segmentation by the line $d d'$ proves that

$$d' S' : d' S'' = P'' S' : P' S'' \qquad (6)$$

Hence, in order to find the principal planes of a system, determine the position of a point in the axis, the distances of which from the two refracting surfaces are to each other as the focal lengths of these surfaces in the medium between them. Then calculate the place of the images of this point formed by each surface independently of the other, according to formula (3).

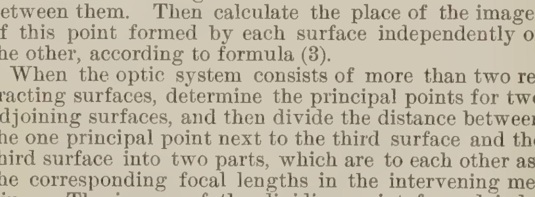


FIG. 2040.

When the optic system consists of more than two refracting surfaces, determine the principal points for two adjoining surfaces, and then divide the distance between the one principal point next to the third surface and the third surface into two parts, which are to each other as the corresponding focal lengths in the intervening medium. The images of the dividing point formed independently by the third surface, and by the system of the other two surfaces, are then the principal points of the system of three surfaces.

19. *The Nodal Points.*—The nodal points of a compound system replace the optic centre of a single refracting surface. For while all rays of direction pass undeflected through the optic centre of a single surface, a second surface will deflect all rays with the exception only of the axial ray. Hence a single optic centre cannot exist in a compound system. But there exist two points in the axis, viz., the nodal points, of such properties that a ray directed toward the first before entering the system pursues a course after its final refraction as if it had passed through the second nodal point parallel to its original direction.

That a pair of points of such properties must exist in any compound system is evident from Fig. 2041, where F' is the first and F'' the second focus, and $m' H' n'$ the first and $m'' H'' n''$ the second principal plane. A ray $B m'$, coming from the luminous points B, forms with the refracted ray $m'' b$ any angle of less than 180° as seen from below, while the ray $B n'$ forms with its refracted prolongation $n'' b$ an angle greater than 180° as seen from below. Somewhere between m' and n' there must be a level where the incident ray includes with its continuation beyond the second principal plane an angle of 180° exactly, in other words, where the two are parallel. Let this be at the level l'. If we prolong the incident ray $B l'$, the points where this prolonged ray and the refracted ray $l'' b$ cut the axis, viz., K' and K'', answer the requirements of the nodal points. The position of the nodal points relative to the principal points is made evident in Fig. 2042.

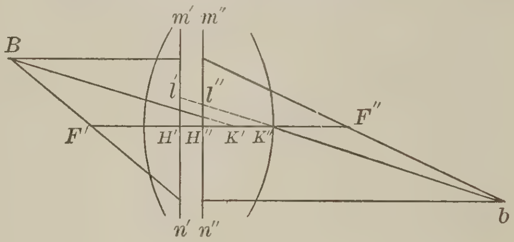


FIG. 2041.

In this figure we will draw the line $B F'$ on F' vertical to the axis. From the point B there proceeds a ray of direction $B K'$ to the first nodal point K'. According to our premises the ray $K'' b$ must be parallel to $B K'$ and in the direction $K'' b$ lies the image of B, at an infinite distance from the optic system. Since the point B lies in the anterior focal plane, every ray proceeding from it is rendered parallel by its refraction to the ray of direction coming from B. Hence the ray $B h'$ parallel to the axis is continued after passing through the second principal plane, as $h'' F''$ parallel to $K'' b$, and hence also to $B K$. From the similarity of the triangle $B F' K'$ and $h'' H'' F''$ it is evident that the distance

$$F' K' = H'' F'' \qquad (7)$$

and by reversing the figure and constructing the course of rays coming from the posterior focal plane, we can similarly learn that the distance

$$F'' K'' = H' F' \qquad (7a)$$

and that hence

$$H' H'' = K' K'' \qquad (7b)$$

which latter corollary is also apparent from Fig. 2041. The position of the nodal points can hence be at once learned by formulæ (7) and (7a), after knowing the position of the principal points and of the foci. And thus we have all data necessary to follow the course of rays through any compound optic system.

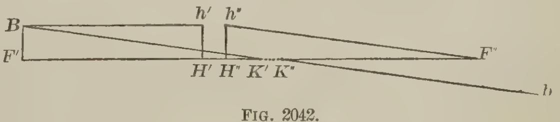


FIG. 2042.

20. *Lenses.*—It will be best to refer briefly to the optic properties of glass lenses before we proceed to the eye

itself. According to the curvature of their surfaces and the distance between them, lenses either reunite into one point all the rays coming from one point, or disperse them. The former, or collecting lenses, have a positive focal length. They form inverted actual images of distant objects, and erect, virtual, and enlarged images of objects nearer than their focus. The latter, or diverging lenses, have a negative focal length, and can form only erect, virtual images, smaller than their object. When both surfaces of a lens are convex, or one is convex and the other plane, the lens belongs to the former variety; when one surface is concave and the other plane, or when both are concave, we have a diverging lens with negative focus. When one surface is convex and the other concave, the positive or negative value of the resulting focal length depends not only on the curvature of the two surfaces, but also on the distance between them.

The refractive index of the glass used for spectacles is so near 1.5 that we can calculate on that basis without important error, at least for spectacles. Taking this index we find that in a plano-concave, or plano-convex lens, the focal length is twice the length of the radius of the curved surface, measuring from the curved surface, according to formula (2) or (2a). The first and second focal lengths are of course equal to each other, when the lens is surrounded by the same medium on both sides, according to (2b). The distance of the foci from the plane surface is, however, not the same as from the curved surface, for the focal lengths are measured from the principal points, one of which coincides with the curved surface, while the other is between the two surfaces. But for most of our purposes we can ignore the thickness of the glass lenses, as long as this is slight compared with the other dimensions, and practically measure the focal length from the surface, or, indifferently, from the centre of the lens. If, hence, we express the focal length of a plano-convex lens as

$$F' = F'' = 2\,r$$

we get for a biconvex lens the formula

$$F = \frac{r' + r_2}{2}$$

If the radii of curvature of the two surfaces are alike, we find the focal length equal to the radius, provided the index of refraction is practically 1.5. This applies similarly to biconcave lenses, F being, however, negative. In lenses with one convex and one concave surface, the measurement of the focal length is not quite so simple, because the thickness of such a lens cannot be ignored without error, and the principal points can in such a combination be outside of the substance of the lens.

The so-called strength of lenses is measured differently, according to the unit which we adopt. Formerly a lens of the focal length of one inch—either negative or positive—was taken as the standard and called 1. Any lens of longer focal distance could be named only in fractions, $\frac{1}{2}$ being one-half of that strength; that is to say, having a focal distance of two inches, and $\frac{1}{12}$ having twelve inches focal length, while a stronger lens, greater than 1, had a corresponding shorter focal distance. Since the adoption of the metric system in ophthalmology, the opposite way of enumeration has been employed. A lens of the focal length of 1 metre is now taken as unit, and called one dioptric, or 1 D. Any lens of longer focal length is expressed in a decimal fraction, thus, 0.25 D means a lens of 4 metres focal length. The stronger lenses, on the other hand, are measured by several dioptrics; thus, 10 D, being a lens of $\frac{1}{10}$ metre, or 10 c.c. focal length. Since both systems of measurement are yet in use, it is best to become familiar with both. As regards the convenience in calculation, for which purpose the dioptric system was introduced, there is really not much difference between them. In order to convert the number of a lens from one system into another, it is to be remembered that the metre is equal to 39.37 English inches, or 36.94 French inches. On account of inaccuracies in grinding glasses, the whole numbers, 40 (English), and 36 (French), are close enough for practical purposes. Hence, to get the dioptric equivalent of an English number, divide that number into 40, and to translate a certain number of dioptrics into the French inch system, divide the number into 36.

21. In order to examine the refraction in the eye we must determine the refractive indices of the different media, the curvature of the surfaces, and the distances between the separate surfaces.

22. *Refractive Indices of the Media of the Eye.*—The refractive indices have been measured by various observers in dead eyes by means of different physical methods. On account of less perfect methods former results must be taken with some caution. Even the more recent determinations made with Abbe's refractometer have yielded not inconsiderable discrepancies among different observers, which may perhaps be attributed to individual variations. The table of refractive indices, given below, is copied from Zehender and Matthieson.[1] It is the most complete of all recent determinations.

The indices of cornea, aqueous humor, and vitreous body are so nearly alike that an average index of the three can be used as a basis for calculation without appreciable error. Helmholtz assumes 1.3365 as the most nearly correct average in his latest publication. While the index of the capsule of the lens is considerably above this figure, this membrane is so thin and its surfaces are so nearly parallel to each other that its influence on the rays can be neglected without error. The index of the lens itself increases from the external layer to the nucleus, so that the lens really consists of a large number of layers of increasing optic density. By reason of this stratified arrangement the total refractive power of the lens is greater than it would be were the entire lens of the refractive index of its nucleus. For each layer, as we proceed toward the nucleus, increases not only in refractive

TABLE OF REFRACTIVE INDICES (ZEHENDER AND MATTHIESON).

Subject.	Cornea.	Aqueous humor.	Anterior capsule of lens.	Lens.			Posterior capsule of lens.	Vitreous body.	Distilled water.
				Cortical layer.	Middle layer.	Nucleus.			
Male, 50 years, I.	......	......	......	1.3953	1.4087	1.4121	1.3455		
II.	1.3770	......	......	1.3853	1.4067	......	1.3658	1.3348	
Female, 45 years, I.	......	......	......	......	1.4044	1.4112			
II.	......	......	......	......	1.4044	1.4094			
Female, 26 years, I.	......	......	1.3600	1.3867	1.4056	1.4154			
Male, I.	1.3772	......	......	1.3902	1.4062	1.4077	......	1.3342	
Unknown, I	......	......	......	......	1.4076	1.4091			
II	......	......	......	......	......	1.4096			
Female, 45 years, I.	......	......	......	1.3930	1.4018	1.4101			
II.	......	......	......	1.3811	1.4073	1.4107			
Child of two days, I.	1.3721	1.3338	1.3821	......	......	......	1.3503	1.3340	
II.	......	......	1.3780	......	......	......	1.3572		
Average	1.3754	1.3338	1.3734	1.3886	1.4059	1.4106	1.3547	1.3343	1.3326

index but also in convexity. This is evident when we compare the following two lenses, the thickness of which must not be more than a small fraction of the focal length. Let one of these lenses, *A*, be homogeneous and have the refractive index *n''*, the index of the surrounding medium being *n*, while the other lens, *B*, has only a core or nucleus more convex than the surface of the lens of the index *n''*, the superficial layer having an index *n'*, intermediate between *n* and *n''*. If *n'* is now very nearly equal to *n*, we have practically a lens of the same index as that of the lens *A*, but of shorter radius of curvature, and hence of shorter focal length. If *n'*, however, is very nearly equal to *n''*, the lens *B* will be practically of the same strength as the lens *A*, but never less. Hence, no matter in what ratio the index increases as we proceed toward the nucleus, the lens gains thereby in strength. The special advantages of this stratification over a homogeneous lens is the more regular refraction of rays very oblique to the axis, as has been shown mathematically by Hermann.[2] Thereby the images of objects situated laterally from the axis of the eye are not distorted as they would be when projected by a glass lens. The actual refraction of the excised human lens was found by Helmholtz in two measurements to be equal to that of a homogeneous lens of the same curvature, but with a refractive index = 1.4519 and 1.4414. But in his latest estimate (1874) he adopts 1.4371 as the more nearly correct average total refractive index of the lens in its normal attachment during life.

23. *Curvature of the Ocular Surfaces.*—The curvature of the surfaces cannot be measured with accuracy in the dead eye, on account of the altered tension of the eyeball. In the living eye the curvature can be calculated from a measurement of the size of images reflected from the surfaces. The cornea, for instance, acts as a polished convex mirror, producing diminutive images, apparently behind its surface. The size of such an image is to half the radius of curvature of the mirror as the size of the object is to the distance of the object from the cornea. The size of the image is most conveniently measured by means of Helmholtz's ophthalmometer. This consists of a telescope, in front of which there is a thick plate of glass with parallel surfaces, which has been cut in two, so that the line separating its two halves exactly bisects the field of the telescope. The two plates can be turned on an axis vertical to the line of separation. As long as the two plates are practically one, that is to say, lie in one and the same plane, objects are seen through them in their natural shape; but when the two plates are turned in opposite directions, the objects appear split into two halves, which are displaced laterally in opposite directions, in proportion to the rotation of the plates. The explanation of this displacement has been given in Section 3. For actual use the ophthalmometer is directed toward the observed eye, at a distance of several metres, and the images of two lights, one placed on either side of the telescope, or, rather, the ideal line uniting the two lights, are observed as reflected from the cornea. The two lights are, of course, placed in the prolongation of the line separating the two glass plates of the instrument. These plates are then turned by a screw until the image is doubled; that is to say, until the two halves are displaced laterally through the open space occupied by the image. From the observed degree of rotation, and the thickness of the plates, the extent of displacement, and hence the size of the image, can be calculated, and thereby the radius of curvature of the cornea be determined.

The radius of curvature, measured by reflection from the middle portion of the cornea, has been found to vary in different eyes from 7 to 8.2 mm., an average near 7.8 mm. being the most common. No definite relation has been found between this radius and any existing ametropia. On observing the reflection from the marginal portion of the cornea, it can be seen, even with the unaided eye, that the images are larger than in the centre; that is to say, that the convexity of the cornea diminishes from the centre toward the periphery. The cornea is therefore a segment of a sphere, only in its central area, while toward the periphery its shape approaches that of an ellipse, the major and minor axes of which are to each other in the ratio of about 9 to 10 or 11. The posterior surface of the cornea is found in the dead eye to be nearly concentric with the anterior surface. This fact, in connection with the rather slight difference in the indices of cornea and aqueous humor, allows us to regard the cornea, aqueous humor, and vitreous body as one optically homogeneous medium, bounded by a single surface.

The radius of curvature of the anterior surface of the lens has been found to vary between 9 and 12, and exceptionally even 14 mm.; and that of the posterior surface between 5.5 and 6.5. The images reflected from these surfaces are so faint, on account of the small difference in the refractive indices of aqueous humor and lens, that the ophthalmometer can be used to advantage only with sunlight. The apparent size of these images requires a correction, for the cornea and aqueous humor act as a magnifying lens, interposed both in the path of the rays from the object to the reflecting surface, and, again, between the latter and the ophthalmometer. In the case of the images reflected from the posterior surface of the lens, the substance of the lens must also be taken into account as part of the magnifying system. It is necessary hence to know the distance from the cornea to the anterior surface, and from the latter to the posterior surface of the lens in order to calculate the radii of curvature. The posterior surface of the lens acts as a concave mirror, giving an inverted and very small image.

24. *Distances between the Refracting Surfaces.*—The distance of the anterior surface of the lens from the cornea has been determined according to various methods by Helmholtz and his pupils. By means of a focussing microscope with graduated screw, or by means of the ophthalmometer with the aid of movable lights, it was learned how far the rim of the iris appears behind the cornea and the true position of the pupil was then calculated from the known refractive power of cornea and aqueous humor. Values between 3.2 and 4 mm. have been found in different eyes. Helmholtz adopted 3.6 mm. as a sufficiently accurate average to use in his diagrammatic eye. The distance of the posterior surface of the lens from the cornea can be measured only by complicated methods based on the observation of the parallax between the reflection from the cornea and that from the posterior surface of the lens, and by taking into account the influence of cornea, aqueous humor, and lens substance on the rays. It has been found to approximate very closely to 7.2 mm., which gives 3.6 mm. as the average thickness of the lens (while the eye is not accommodating). The lens taken out of the eye increases in thickness on account of elastic retraction, as will be explained in the section on Accommodation.

25. *Diagrammatic Eye.*—We learn thus that there are noticeable differences in the optic constants of normal eyes, so that two eyes, both emmetropic, are not necessarily identical in construction. But within the latitude of emmetropic eyes the deviations of the different figures from the average counterbalance each other, so that the object, the formation of sharp images of distant objects in the plane of the retina, is equally attained in all. From numerous measurements made by himself and others, Helmholtz has constructed the following diagrammatic eye, corresponding to the average figures of human emmetropic eyes:

	Millimetres.
Refractive index of cornea, aqueous, and vitreous humor	1.3365
Refractive index of the lens as a whole	1.4371
Radius of curvature of the cornea	7.829
Radius of curvature of the anterior surface of the lens.	10.
Radius of curvature of the posterior surface of the lens.	6.
Distance from the anterior surface of the cornea to the lens	3.6
Thickness of the lens	3.6

From these data are computed:

Anterior focal length of the cornea, aqueous and vitreous humor	23.266
Posterior focal length of the cornea, aqueous and vitreous humor	31.095

	Millimetres.
Focal length of the lens (in place)	50.671
Distance of first principal point of the lens from its anterior surface	2.12
Distance of second principal point of the lens from its posterior surface	1.274
Distance of the first principal point H' of the entire eye behind the cornea	1.750
Distance of the second principal point H'' of the entire eye behind the cornea	2.115
Distance of the first nodal point K' of the entire eye behind the cornea	6.966
Distance of the second nodal point K'' of the entire eye behind the cornea	7.331
Anterior focal length of the entire eye	15.508
Posterior focal length of the entire eye	20.719

This latter figure plus the distance of H'' from the cornea gives us 22.834 mm. as the optic axis from the anterior surface of the cornea to the sensitive plane of the retina and adding to this number the thickness of the sclerotic coat, viz., 1.3 mm., we obtain about 24.1 mm. as the length of the eyeball. Anatomical measurement has shown the eyeball to vary between 22.5 and 27 mm. in length, 24 to 24.6 mm. being the most common limits. Unfortunately these anatomical measurements refer mostly to eyes the refractive state of which was not determined during life. The diagrammatic eye of Helmholtz and the position of its cardinal points are illustrated by Fig. 2043, amplified twice.

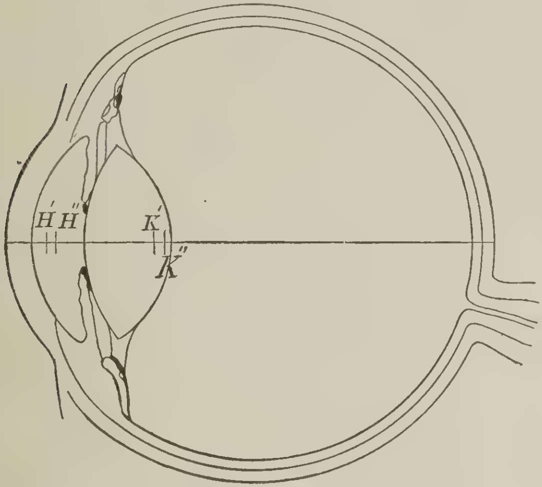


FIG. 2043.

26. In the calculation of the size of retinal images and of the influence of glasses on sight in fact, in almost all the problems not relating to the changes during accommodation, we can arrive at results sufficiently accurate by taking as a basis the simplified diagrammatic eye of Donders, in which the lens is omitted. It consists of a single refracting surface, representing the cornea with a radius of curvature of 5 mm. The single internal medium, optically identical with the cornea, has a refractive index of 1.333 ($\frac{4}{3}$). Thereby we deal with but one principal point, viz., in the plane of the cornea and but one nodal point, the centre of curvature of the cornea. The first focal length is 15 mm., the second 20 mm., which latter figure represents likewise the length of this eye.

The human eye has some advantages not possessed by artificial optic instruments, but also various faults which a skilful optician can avoid.

27. *Visual Field.*—There exists no instrument which has as extensive a field as the eye, since images are depicted on the retina of objects situated as far as 55° to 65° from the line of direct sight, and on the temporal side even as far as 90° to 100°. The fact that images formed near the periphery of the retina are not seen distinctly, is due principally to the relative dulness of sensibility of the peripheral portion of the retina. The images themselves are quite sharp, as we can learn by examining the periphery of the retina in the eye of another person with the ophthalmoscope. When the refraction is emmetropic in the centre of the retina, it is very nearly so also in the extreme periphery. This is due to the curvature of the rear of the eyeball and of the retina (compare Section 9). Moreover, the elliptical curvature of the cornea, and still more the stratified structure of the lens prevent the distortion of images, which ordinary spherical, homogeneous lenses would produce in the case of objects situated far laterally from the axis of the system.

28. *Spherical Aberration.*—Spherical lenses do not collect in the common focus those rays which are very oblique to the axis or strike the refracting surface far from its centre. This spherical aberration is shown in Fig. 2027. In the eye it is almost wholly obviated by the elliptical shape of the cornea and the stratification of the lens. The iris, moreover, serves the purpose of a diaphragm, so that the extreme marginal rays cannot ordinarily pass through the pupil.

29. *Chromatic Aberration.*—The chromatic aberration of lenses gives rise to colored rings around images otherwise well defined. It is due to the fact that the index of refraction is not the same for waves of light of different length. Hence there is necessarily a slight separation of the different colors when mixed or so-called white light is refracted by a lens. The eye is not free from this defect; it possesses it to about the same extent as if it consisted of water. If either end of a sharply defined spectrum be observed through an achromatic telescope the other end appears diffuse until the adjustment of the telescope (or of the eye) is altered. The difference in adjustment corresponds to about 1.5 to 2 dioptrics; that is to say, an eye forming a sharp image of an object emitting violet light, requires an additional convex lens of some 75 to 50 c.c. focal length, in order to bring the less refrangible red rays into a focus upon the retina. Ordinarily we are not conscious of this defect, because the eye is adjusted for the middle and brightest portion of the spectrum, viz., yellow and green to blue, while the red and violet rays form circles of diffusion around the image, which blend, and thereby diminish in distinctness of color, being, moreover, much less bright than the sharply defined image which they surround. But we can see these colored circles of diffusion quite distinctly on looking at some bright object, while covering one-half of the pupillary aperture with an opaque screen, for by thus cutting off half of the pencil of light, we prevent the blending of the color rings, and the object shows then a blue edge on one side and a yellow margin on the other. The chromatic aberration is also quite noticeable on observing a luminous point through a violet glass, which absorbs the middle part of the spectrum, whereupon we see either a red point surrounded by a blue halo, or a red margin around a blue point of light, according to the refractive state of the eye.

30. *Imperfect Centring.*—The optic system of the eye is not perfectly centred. The centre of the cornea coincides, indeed, with the vertex of its ellipse; but the major axis of this ellipse forms an angle with the visual line, or line of direct sight; that is to say, the line of the ray of direction passing from an observed point through the nodal points to the centre of the retina. The visual line deviates toward the nasal side of the corneal axis (proceeding outward) to an extent of from 4° to 8°. This relatively oblique direction of the corneal axis, when extreme, may give some eyes a false appearance of divergent squint. Still no noticeable deficiency of sight can be attributed to this want of centring.

31. *Astigmatism.*—More serious defects are those due to irregularities in the curvature of the refracting surfaces. We have so far considered only the refraction of rays which lie in one plane, with the tacit assumption that our refracting surfaces are the surfaces of true bodies of rotation, that is to say, that the radii of curvature are equal in all meridians. For, in this case, any of the figures illustrating the course of rays in the plane of the paper may be supposed rotating on their axis in order to illustrate the course of rays in all planes. But this assumption is scarcely ever correct in the case of the human

eye. On measuring with the ophthalmometer the corneal radius of curvature in the horizontal, and then in the vertical meridian, the two radii are found to differ from each other to a trifling extent even in the most normal eyes. More commonly, but not always, the radius is smallest in the vertical meridian. The two meridians presenting the greatest discrepancies are not necessarily horizontal and vertical; they may have any inclination. A difference of 0.1 mm. between the radii of two meridians at right angles to each other separates the focus of one meridian from that of the other to the extent of about 0.3 mm. Differences of 0.01 to 0.05 mm. in the radii are the most common. The cornea is hence the segment of an ellipsoid with three unequal axes. As a result, the focal length is not the same in any two meridians of unequal curvature, and hence the points of an object cannot be represented by points in the images formed in such an eye. If in Fig. 2044, *A*, we represent the ellipsoid cornea with the horizontal meridian *h h* having a greater radius of curvature than the vertical meridian *v v*, the focus in the former meridian *f h* must be farther off than *f v*, the focus of the vertical meridian. If we place a screen successively in the positions numbered 1, 2, 3, 4, and 5, the image of a distant point would appear as shown in an exaggerated manner at *B*, 1, 2,3, 4, and 5 of the same figure. The refraction by such an ellipsoid cornea can be imitated by means of an ordinary spherical lens, to which is added a cylindrical lens, the segment of a cylinder, thereby introducing a difference in the refractive strength in the two meridians, of which one is parallel with, and the other at right angles to, the axis of the cylinder. This defect of the eye is known as the regular astigmatism (from *α*, privative, and *στίγμα*, a point). There are very few, if any, eyes entirely free from it. When the inequality in the refraction of two meridians exceeds the strength of about one-half to one dioptric, it may necessitate correction by means of cylindrical glasses (see under *Astigmatism*). As the result of regular astigmatism, lines of different inclination are not seen equally distinctly. If, for instance, the eye be accurately emmetropic in the horizontal meridian, while the sharper curvature of the vertical meridian brings the focus behind the retina in the latter meridian, then only vertical lines at infinite distance will be sharply defined on the retina, while the more a line approaches the horizontal direction, the more diffuse will be its retinal image. The interference with sharp sight increases, of course, with the degree of astigmatism. A discrepancy between two meridians amounting to less than half a dioptric does not interfere with sight to any practical extent.

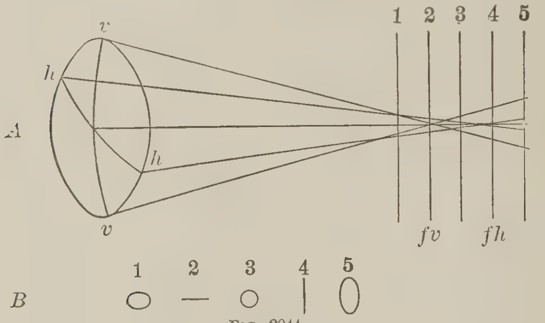


FIG. 2044.

Irregular Astigmatism gives rise to such slight imperfections of retinal images as the radiation of "rays" around stars and other small luminous points. It is due to optic inequalities in the different sectors of the lens, whereby some of the rays are deflected from the path which they would pursue in a perfect eye. This irregular astigmatism does not exist after the lens has been removed.

32. *Muscæ Volitantes.*—Few, if any, eyes do not at times see flying specks, so-called muscæ volitantes. They appear in the form of transparent rows of beads or groups of granules, or simply shadowy streaks floating about when the eye is moved. They are due to the presence of similarly shaped objects floating in the vitreous body, cells and groups of cells, and shreds of membranes, transparent, but of an index of refraction slightly different from that of the medium surrounding them. Their rims hence cast shadows similar to those of a glass ball between a light and a screen. These shadows are most marked when the rays of light are parallel in the vitreous body, when the source of light is in the anterior focus of the eye. We can observe them well by using as source of light a pinhole in an opaque screen held close to the eye and toward the sky, or on looking into a microscope. When the attention has once been called to them they may continue to annoy nervous persons, mentally rather than optically. These shadows, even if inconvenient, are not indicative of any disease.

33. *Ametropia.*—The last and most important imperfection of the eye is the not uncommon want of harmony between the focal length and the anatomical length of the eyeball, the refractive defect known as ametropia. We have seen that the radii of curvature, the distance from cornea to lens, the length of the eyeball, and perhaps even the refractive indices, may vary within certain limits in different eyes. It is only in the more fortunate instances that the ideal result, viz.: the coincidence of the posterior focal plane with the position of the retina, is obtained, while in many eyes, otherwise healthy, images of distant objects are formed, either in front of the retina, constituting myopia, or behind the retina, the condition of hypermetropia. In either of these two cases the retinal images of distant objects are blurred in proportion to the distance of the retina from the focal plane, and in proportion to the size of the pupil. The lower degrees of ametropia may be due to an unproportional curvature of the corneal and lenticular surfaces, while the length of the eyeball is normal; but when the anomalies of refraction reach any high degree, the eyeball is found, not merely relatively, but absolutely too long in myopia, too short in hypermetropia.

While emmetropia is the most fortunate refractive condition, it is not necessarily the most common. Statistics show that in the upper classes of schools, and especially high schools, in European countries, from one-third to one-half, and sometimes even two-thirds of the eyes are near-sighted, and some five to ten per cent. are far-sighted. In this country the figures are a little more favorable, as regards the frequency of emmetropia. Fuller details of these statistics will be given under the heading *Myopia*.

34. *Refraction during the Growth of the Eye.*—In the infantile eye all the dimensions are, of course, smaller than in the adult organ. The shorter axis of the eyeball is, however, proportionate to the shorter radii of curvature of cornea and lens, so that emmetropia can exist. Indeed, during childhood there are more emmetropic eyes than in adult life. The eyes of babes, however, are most frequently far-sighted, as shown by ophthalmoscopic examination. Jaeger formerly asserted the contrary, having found 78 eyes myopic out of 100, and but 5 accurately emmetropic in new-born babes. He seems to have been misled, however, by the accommodated condition of the infantile eye, for later observers, who paralyzed the accommodation by means of atropine, have arrived at different results. Thus Eli[3] found but 11 eyes myopic, 17 emmetropic, and 72 hypermetropic in 100 eyes of infants. Bjerrum[4] noted 61 hypermetropes, 23 emmetropes, and 3 myopes on examining 87 babes. Horstmann[5] found in 50 new-born infants 88 far-sighted eyes, 10 emmetropic, and but 2 short-sighted eyes. In 50 children, of the age of one or two years, 84 eyes were far-sighted, 10 normal, and 6 short-sighted; while in 50 children, four to five years old, hypermetropia had diminished, involving 74 eyes; myopia had increased to 13 eyes; 13 eyes being emmetropic. These figures show that the refraction increases ordinarily as the child advances in years. During the years of school attendance this growth leads, in many instances, to a myopic refrac-

tion. Indeed, as we pass from the lower to the higher classes in schools, we find myopia increasing steadily in frequency and in degree. The refraction remains stationary from the time of puberty, in healthy eyes. The increase of myopia so often noted from this time on until about the thirtieth year must be considered a morbid change.

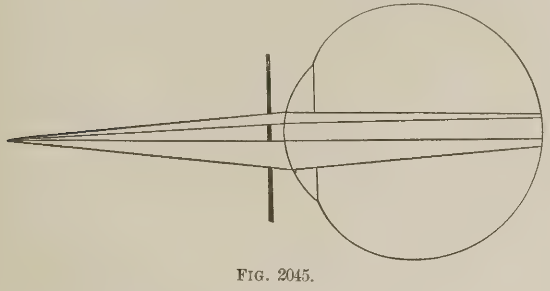


FIG. 2045.

35. Beyond the sixtieth year of age the refraction diminishes again, so that emmetropia turns into slight hypermetropia, on account of senile changes in the lens.

36. ACCOMMODATION.—According to the laws of refraction, the emmetropic eye can form sharp retinal images of those objects only which are situated at an infinite distance from the eye, or at least at a distance very large when compared with the dimensions of the refracting surfaces. Practically this amounts to any distance beyond 5 metres. But every-day experience teaches us that we can also see distinctly objects quite close to the eye; but we can never see equally distinctly, and at one and the same time, two objects, one far and the other near. On looking at a distant sign through a veil held in front of the eye, we can get alternately sharp images of the distant letters or of the threads of the adjacent veil, but we cannot see them both distinctly at one and the same time. This power of successive adjustment of the eye for distant and adjacent objects is termed the faculty of accommodation.

The exertion of the accommodation increases for the time being the refractive strength of the eye. It is evident that an eye accommodated for an object four inches distant must be equal in refractive strength to the emmetropic eye plus the strength of a convex lens of four inches focal length. For were the eye deprived of its power of accommodation it would be necessary to add to it the strength of this lens in order to get sharp retinal images of objects four inches off. The accommodative effort of an eye can therefore be represented by the strength of a convex lens of a focal length equal to the distance from the eye to the object accommodated for.

37. *Changes in the Eye during Accommodation.*—The optic changes upon which accommodation depends occur solely in the crystalline lens. Neither the corneal curvature nor the position of the retina is altered. Removal of the lens deprives the eye completely of its power of accommodation. Any eye, except one extremely myopic, becomes highly hypermetropic upon removal of the lens, requiring then a strong convex glass in order to see distinctly at a distance. On account of the impossibility to accommodate, the strength of this glass must be increased for near objects, and with a given glass accurate sight is possible only at one given distance. If the individual can read at different distances, it is done by ignoring the circles of diffusion, especially when they are small, on account of a narrow pupil. The most rigid test—whether in this or in any other case an eye is adjusted for a certain distance—is known as Scheiner's experiment.

38. *Scheiner's Experiment.*—If some luminous point—for instance, a pinhole in a screen in front of a light—be viewed through two pinholes in another screen which are closer together than the diameter of the pupil, the only effect of the latter screen held close to the eye will be to diminish the number of rays, and thereby reduce the brightness of the retinal image, if the latter be sharply defined on account of proper adjustment of the eye for the light. But if the eye is not adjusted for that distance, and circles of diffusion are formed on the retina, the screen with two perforations will cut off the rays forming the middle portion of the diffuse image, leaving instead two separate images of the luminous point, to which the eye is much more sensitive than to the circles of diffusion. Hence any want of adjustment causes the luminous point to appear double, as is evident from Fig. 2045.

39. *Changes in the Shape of the Lens.*—During accommodation the lens becomes more convex, especially its anterior surface, which also moves forward on account of the thickening of the lens. If we place a light slightly to one side of an observed eye and watch the images reflected from the various surfaces, they will appear as seen in Fig. 2046, *A*, while the observed eye looks as a distant object. When the eye observed is then adjusted for some near object, the images change, as seen in *B*, Fig. 2046. The corneal image, *a*, remains the same in both cases. The reflection from the anterior surface of the lens, *b*, diminishes in size, indicating increased curvature of the surface, and moves laterally toward the corneal image, a motion referable to the advancement of the anterior surface of the lens. The small, sharply defined, and inverted image (*c*) produced by the concave posterior surface of the lens shrinks likewise slightly in size, showing that the radius of curvature of that surface diminishes as well, though but little. No indication of any motion of the posterior surface can be observed. These changes in the curvature of the lens have been more accurately measured with the ophthalmometer, which shows that the radius of curvature can be reduced during a strong accommodative effort to about 6 mm. for the anterior surface, and about 5.5 mm. for the posterior surface of the lens, while the thickness of the lens may increase from 3.6 to 4 mm. Thereby the focal length of the lens in the diagrammatic eye would be reduced from 50.671 mm. during rest to 39 mm. during a strong accommodative effort. Calculating on this basis the refractive strength of the diagrammatic eye, we shall now find the principal posterior focus 1.644 mm. in front of the retina, while the retina itself is in the plane of focal reunion for rays coming from an object 146.6 mm. (not quite six inches) distant from the first principal point, which latter is 1.566 mm. behind the cornea in such an accommodated eye. Mathematical analysis thus confirms that the increased curvature and the advancement of the front surface of the lens suffice to account for the accommodative changes.

During accommodation the pupil diminishes in size. The utility of this contraction of the iris is evident on remembering that, according to Section 4, the spherical aberration would increase with the divergence of the rays, and hence with the proximity of the object. On account of the advancement of the front surface of the lens the iris is also moved forward, which can be seen on looking in profile view at an eye during accommodation.

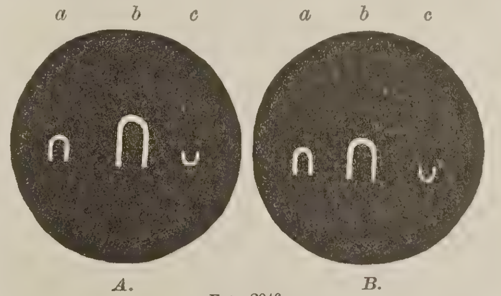


FIG. 2046.

40. *Mechanism of Accommodation.*—The accommodative changes of the lens are brought about by the action of the ciliary muscle. The lens itself is not a muscular organ, it is devoid of contractility. It is, however, an

elastic body kept stretched by its attachment to the annular ligament, as an elastic hoop would be flattened by the traction of two cords attached at two opposite points.

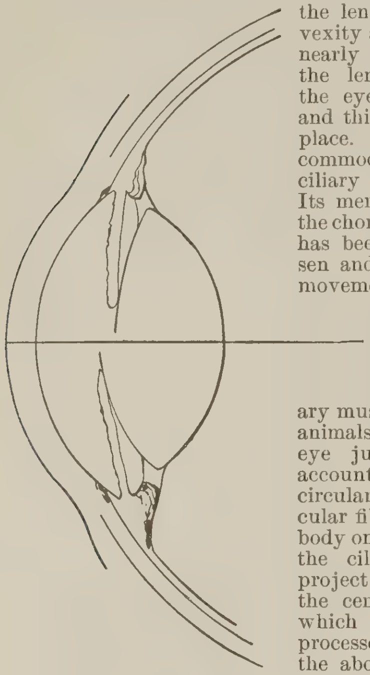


FIG. 2047.

Relieved of this traction the lens increases in convexity and becomes more nearly globular, so that the lens removed from the eye is more convex and thicker than while in place. During the accommodation effort the ciliary muscle contracts. Its meridional fibres pull the choroid forward. This has been shown by Hensen and Voelkers, by the movements of a needle put through the sclera and choroid on sending an electric current through the ciliary muscle in the eyes of animals and in a human eye just extirpated on account of disease. The circular, ring-shaped muscular fibres of the ciliary body on contracting cause the ciliary processes to project further toward the centre of the pupil, which movement of the processes is favored by the above-described traction on the choroid and consequent relaxation of its anterior insertion. In eyes in which a sufficiently extensive segment of the iris has been removed by the operation of iridectomy, and through the translucent intact iris of albinos, this advancement of the ciliary processes toward the centre of the pupil has been directly observed. Since the ligament of the lens is attached to the ciliary processes the crowding of this ring-shaped structure into a narrower space necessarily relaxes the circular band stretched across the aperture within this ciliary ring. Thus the lens is permitted to retract by yielding to the tension of its own elastic substance; for the arrangement of the fibres of the lens substance is such that they are relaxed by the approach of the lens toward the globular shape, while the flattening of the same by traction of its ligament puts them on the stretch. The changes in an eye during extreme accommodation are shown in Fig. 2047, in which the upper half represents the front half of the eye at rest, and the lower half the contraction of the ciliary muscle and its effect upon the shape of the lens.

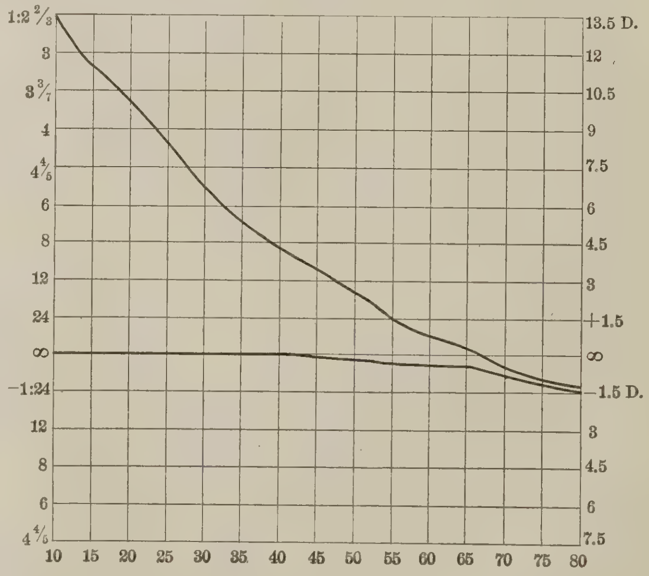


FIG. 2048.

41. *Range of Accommodation.*—The most distant point of which the eye at rest can form a sharp image on its retina has been termed by Donders the *far point* (punctum remotum = R) of the eye. In the emmetropic eye the far point is—according to our definition of emmetropia—at an infinite distance. The myopic eye, however, cannot see distinctly beyond a certain short finite distance, depending on the degree of shortsightedness, while in hypermetropia the eye cannot bring into focal reunion on the retina any but convergent rays, and the far point is therefore negative, that is to say, situated at some finite distance behind the eye. The fact that many hypermetropes can see distinctly at a distance with the unaided eye, is due to their using a part of their accommodation continuously in order to increase the actual refraction of the eye. The *near point* (punctum proximum = P) on the other hand, is the nearest point of which the accommodated eye can get a well-defined image. The range of accommodation is the total accommodative power which an individual eye possesses. We can represent it by the strength of the lens equivalent to the refractive difference between the eye at rest adjusted for the far point and the eye accommodated for the near point. Thus, an emmetropic eye, which can see distinctly an object as close as five inches, has a range of accommodation representable by a lens of five inches focal length or of the strength of about 8 D. For deprived of its accommodative power this eye would require such a lens to be held in front of it in order to get a sharp image of this near object on its retina. Practically, it will do to hold the lens very close to the cornea; for theoretical accuracy, however, the lens in question, of an infinite thinness, must be assumed situated in the first principal plane of the eye. The significance of the range of accommodation is made plainer by the use of Donders' formula,

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R},$$

in which we represent by A the range of accommodation, by P the near point, and by R the far point. This formula is applicable to ametropic eyes as well as to emmetropia, for anomalies of the refraction do not necessarily alter the range of accommodation. Thus a myope whose far point is at twelve inches' distance, and who can accommodate for objects four inches from the eye has an accommodative range $= \frac{1}{4} - \frac{1}{12} = \frac{1}{6}$. Another instance will illustrate both the condition in hypermetropia and the use of the dioptric system. Suppose a certain hypermetropic eye, the axis of which is so short that it requires a correcting glass of 4 D in order to obtain sharp retinal images of distant objects. In this eye the far point is negative, that is to say, it is situated 25 cm. behind the anterior principal point. If this eye possesses an accommodative range equal to eight dioptrics, four of them are required to see distinctly at a distance and only 4 D are left, enabling the person to get distinct images of objects 25 cm. distant by the extreme employment of his accommodation. Donders' formula reversed expresses this on using centimetres as follows:

$$\frac{1}{P} = \frac{1}{R} + \frac{1}{A},$$

which is in numerals

$$\frac{1}{P} = -\frac{1}{25} + \frac{1}{12\frac{1}{2}} = \frac{1}{25},$$

or employing dioptric notation, which is the reciprocal of the focal length,

$$P = -4\,D + 8\,D = 4\,D;$$

in other words, the distance of the near point from the eye is equal to the focal length of a glass of 4 D strength = 25 cm.

42. *Influence of Age on the Accommodation.*—From childhood on, the rigidity of the crystalline lens increases, and the extent of its elastic retraction diminishes. Hence the range of accommodation diminishes as the years advance, because the lens cannot retract as much in the later period of life as during youth, though the contracting ciliary muscle relaxes the annular ligament. The range of accommodation sinks thus from beyond ten dioptrics, during childhood, to zero toward the age of sixty years. Donders has constructed a diagram (Fig. 2048), based on numerous observations, which illustrates this decline in a graphic manner. The heavy line (the lower one) represents the refraction of the eye at rest. As before stated, the emmetropic eye becomes slightly hypermetropic in advanced age, presumably from an actual flattening of the lens or a diminution of its refractive index. The range of accommodation extends from the heavier line of passive refraction to the thin line indicating the extreme active adjustment of the eye. The figures at the bottom give the age in years; those at the side the (active or passive) adjustment in French inches (or expressed in dioptrics on the right side). Occasionally deviations are found from this standard of decline. Thus, among others, the writer has seen a gentleman, seventy years of age, who could read the finest type up to eight inches' distance. He had a slight myopia and myopic astigmatism, less than 1 D, so that this accommodative range was still a trifle over 4 D, a very unusual amount for his age. Exceptions of the opposite kind, a falling short of the accommodative range normal to the age of the patient, are always due to disease of the eye or general impairment of the health.

43. *Innervation of the Accommodative Apparatus.*—The ciliary muscle derives its nerve supply from the third cranial nerve or motor oculi, which sends the motor root to the ciliary ganglion, whence issue the ciliary nerves which penetrate the sclera. It is a common clinical observation to find paralyses of other branches of this nerve accompanied by paralysis of the mechanism of accommodation. Experiments by Trautvetter[6] have shown that the fibres of accommodation run in the trunk of the motor oculi in pigeons, while in other animals the results were negative. In dogs, Hensen and Voelkers have traced the fibres up to the floor of the third ventricle of the brain, as shown by the result on stimulating those parts.

Although the ciliary muscle consists of unstriated fibres in mammals, its movements are both as rapid and as much under the control of the will as those of any striated muscle. In birds, indeed, having evidently a very energetic accommodative mechanism, the ciliary muscle is striated. While the ciliary movements are voluntary in a certain sense, we are ordinarily not conscious of any accommodative effort. The movements of the ciliary muscle are guided by the retinal impressions which we get of the objects viewed, and may hence be classed among the complicated cerebral reflex movements. The accuracy of these movements is wonderful, inasmuch as the most rapid changes of adjustment of the eyes for different distances never give rise to any blurring of the images for which the eye accommodates. The regulating mechanism does not miscalculate the distance of the objects. The accommodating movements are always accompanied by an exactly corresponding convergence of the two eyes, so that in normal instances the object accommodated for is also the one toward which both eyes are directed, so as to place its image in the centre of the retina of each eye. The association of the movements of accommodation and convergence is so intimate that we cannot voluntarily perform either movement to any appreciable extent without the other. But by optic means, which simulate the effect of one or the other movement, we can temporarily rupture the association. Thus, with a given degree of convergence for a certain fixed object, we can either force ourselves to a greater accommodative effort by looking through concave glasses, or relax the accommodation by means of convex spectacles. Similarly, we can vary the degree of convergence associated with a certain accommodative effort by placing prisms of variable strength and inclination in front of one or both eyes. The ability to separate these two movements ordinarily associated is increased by practice. It is evident that the correlation of the two movements, as well as the disturbance of this association by optic means, subserves the same purpose, viz., distinct vision without double images.

44. *Movements and Nerves of the Iris.*—On account of the association with the accommodation, the movements of the iris can be best discussed in this connection. The iris serves the purpose of an optic diaphragm, the aperture of which can vary in size according to necessity, the physiological limits being from 1 to 6 mm. diameter. By reflex action the pupil contracts with increasing illumination, thereby diminishing both the fatiguing brightness of the retinal image and the width of any circles of diffusion due to optic imperfections. When the light is relatively feeble, a large pupil, on the other hand, permits a relatively greater brightness of the retinal images, while the enlarged circles of diffusion do not blur the sight so much, on account of their feebler intensity. The pupil contracts also with each accommodative effort, thereby diminishing the spherical aberration, which the proximity of the object and the increased convexity of the lens would produce. Independently of external light, the pupil is very narrow during sleep and during artificial narcosis. The mechanism of this latter contraction is not yet known. When the narcosis is interrupted by any sensory stimulation, or by asphyxia, the pupil indicates this change by dilatation.

The nerves of the iris are the ciliary nerves, coming from the ciliary ganglion, which, in man, has three roots—the short root from the motor oculi, the long root from the naso-ciliary branch of the fifth nerve, and the sympathetic fibres reaching the ganglion along with its arteries. The motor oculi controls the sphincter muscle of the iris. Its experimental irritation contracts the pupil; its section, or accidental paralysis, allows it to remain dilated. The reflex pupillary contraction produced by light starts with the excitation of the optic nerve. When the optic nerves are rendered inactive by disease, the normal play of the pupils ceases, and they remain in a state of moderate dilatation. Excitation of one optic nerve, however, controls the pupils of both eyes, at least in those animals which, like man, have a visual field common to both eyes. Hence, in cases of unilateral blindness, the two pupils are usually alike in size. The centre concerned in this reflex action is the anterior half of the tubercula quadrigemina (Budge). Various instances of diseases of higher parts of the brain have been observed with integrity of these parts, and hence sensitiveness of the pupils to light, although conscious sight did not exist. According to Brown-Séquard the muscular tissue of the iris itself is somewhat sensitive to light, a tonic contraction being induced in it by strong light, even after extirpation of the eyeball.

The sympathetic nerve fibres control the dilator muscle of the iris. The existence of these radiating muscular fibres, which seemed pretty well established by the researches of Henle, Iwanoff, and Merkle, after much controversy with Gruenhagen, has lately been questioned again by Eversbusch (meeting of the Heidelberg Ophthalmological Society, September, 1884). He maintains that the radiating fibres in the posterior layer of the iris, which have been interpreted as smooth muscular fibres, are really nerve fibres, as shown by various staining methods. If these statements are corroborated, it will be impossible to account satisfactorily for the action of the sympathetic nerve on the iris. The view that these nerves change the size of the pupil, through their action upon the muscular walls of the blood-vessels of the iris, is not well supported by the facts.

Their course toward the eyeball is partly along the walls of the arteries, partly along anastomoses which join the fifth cranial nerve. Section or paralysis of the sympathetic nerve of the neck is followed by contraction of the pupil, while its irritation dilates that aperture. These fibres can be traced through the rami communicantes of the last two cervical and the first two dorsal nerves into the spinal cord (Budge and Waller). The reflex centre of these fibres is partly in the corresponding region of the spinal cord, and partly in the medulla oblongata. Reflex dilatation of the pupil through this nerve channel can be readily induced by any sensory impression through almost any sensory nerve, at least when the pupil is not contracted by strong light, especially during sleep and incomplete narcosis. The pupil, indeed, is very sensitive to irritations of sensory nerves. It is not known that this reflex dilatation is of any utility.

It has recently been asserted by Tuwim[7] that the superior cervical sympathetic ganglion maintains a slight tonus of the dilator nerves of the iris, independently of, and even after, its separation from the central nervous system. Although his experiments seem conclusive, the question should be further investigated, since this would be the first instance known of tonic activity of nerves maintained by a sympathetic ganglion.

The fifth cranial nerve is the sensory nerve of the iris, endowing it with very great sensibility. Irritation of this nerve contracts the pupil very energetically in some animals, for instance the rabbit. Section of the nerve has the same effect, temporarily, the fibres being evidently kept in a state of transitory irritation by the injury, as occurs as well in certain other nerves. This influence of the fifth nerve upon the pupil does not exist in carnivorous animals. The observations in disease of that nerve in man are too conflicting to be decisive. The study of eye diseases attended with irritation renders it very likely that in man the fifth nerve is the vaso-dilator nerve of the iris, and that its reflex excitation congests the iris and contracts the pupil mechanically by the engorgement of the vessels. This is also the most plausible explanation of the intense pupillary contraction obtained on puncturing the anterior chamber, which result does not occur on operating on the dead eye.

BIBLIOGRAPHY.—The optic properties of the eye were not understood until Kepler, in 1602, evolved the theory of optical instruments in general. The importance of the various parts of the eye in refraction was further elucidated by the Jesuit Scheiner in 1619. Minor additions were successively brought out by the labor of different authors, but it was only after Gauss had published his mathematical investigation of the cardinal points ("Dioptrische Untersuchungen," Göttingen, 1841) that the complete theory of the refraction in the eye could be deduced. This was done successfully by Listing, in the article "Dioptrik des Auges" in Wagner's "Handwörterbuch der Physiologie" (1853), who, by a critical selection of the older measurements of the refractive indices of the eye by Chossat and by Brewster, of the anatomical measurements of dimensions and curvature by Kraus, Kohlrausch, and others, determined the position of the ocular cardinal points with considerable accuracy. The most marvellously accurate methods, however, for measurements of the living eye, were first introduced by Helmholtz, who, in his "Handbuch der physiologischen Optik" (1867; 2d edition, revised, 1896), has produced a masterly treatise of rare originality, which every student of the subject must consult in the original. Since the publication of his large work, the first part of which on refraction appeared in 1856, Helmholtz has pursued these studies with the aid of numerous students, most of whose articles have appeared in the running numbers of the *Archiv für Ophthalmologie.* In an article by Reich (*Arch. f. Ophth.*, 1874, vol. xx., 1), Helmholtz corrects some of his former measurements and figures, and accepts as more nearly representing the values of the cardinal points in the average eye the figures which we have reproduced in the text of this article. Extensive measurements, especially of the curvature of the cornea, have also been made by Donders ("Anomalies of Accommodation and Refraction," 1864) and by Mauthner ("Vorlesungen ueber d. optischen Fehler des Auges," 1872), and more recently by Reuss (*Arch. f Ophthalmologie*, xvii., 1, p. 27). The entire theory of the formation of images in the eye, including physiological optics in general, is most exhaustively treated in Aubert's "Grundzüge der phys. Optik," in vol. ii. of Graefe and Saemisch's "Handbuch der gesammten Augenheilkunde" (1876), while important recent additions are to be found in Nagel's "Anomalien der Refraction," in vol. vi. of the same work. Very complete is also the treatise of Fick in vol. iii. of Hermann's "Handbuch der Physiologie."* All of these works must be consulted for the complete literature of the subject. In the English language the most extensive but older treatise is the work by Donders on "Anomalies of Accommodation and Refraction" (1864), which book marked quite an era in our knowledge of the physics of the different refractive conditions of the eye. In connection with this latter subject the work of Jaeger ("Einstellungen d. dioptrischen Apparats," 1861) must also be mentioned.

The mechanism of accommodation has been extensively discussed by former authors, by whom, however, no facts were brought forth beyond those taught by every-day observation. By some the accommodative changes were referred to the variations in the size of the pupil, while others even denied the existence of any accommodation. The most complete mathematical discussion was furnished by Th. Young in the "Philosophical Transactions" of 1801, in which it was shown by experiments and by deductions that the accommodation cannot depend on any changes except those in the form of the lens. The experimental proof that such changes do occur was furnished simultaneously and independently of each other by Cramer (in various publications in the Dutch language, between 1851 and 1855) and by Helmholtz (*Monatsberichte d. Berliner Academie*, February, 1853). The mode of action of the ciliary muscle was first explained by Helmholtz theoretically, and has since been confirmed experimentally by Hensen and Voelkers, who have likewise studied the innervation of the accommodative apparatus ("Experimentaluntersuchung über den Mechanismus der Accommodation," 1868, and *Archiv f. Ophthalmologie*, 1873, vol. xix.). Important measurements of the changes in the curvature of the lens during accommodation, and a mathematical inquiry into their efficiency were published by Knapp (*Archiv f. Ophth.*, 1860, vols. vi. and vii.).† Our knowledge of the range of accommodation in health and disease is due mainly to the researches of Donders ("Anomalies of Accommodation and Refraction").

On the innervation of the iris there exists an extensive literature, scattered throughout numerous physiological and ophthalmic serials. The older literature is exhaustively compiled in Budge's "Bewegungen der Iris," 1855. The present writer presented likewise a full review of the physiology of the iris in the Chicago *Journal of Nervous and Mental Diseases* (April and July, 1874), in which the complete literature up to that date can be found. Whatever has been done since 1874 is explicitly referred to in the text.

H. Gradle.

[1] Nagel: Anomal. d. Refraction, in Graefe and Saemisch's Handb. d. ges. Augenheilkunde, p. 461.

[2] Ueber schiefen Durchgang von Strahlenbündeln durch Linsen, Gratulationschrift an C. Ludwig, 1874.

[3] Archives of Ophthalmology, vol. ix., p. 29.

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* The most recent compilation with many original measurements is Tscherning's "Physiological Optics," trans. by C. Weiland.

† Various doubts raised concerning Helmholtz theory of accommodation have been satisfactorily answered by confirmatory researches published by C. Hess in von Graefe's Archiv f. Ophthalmologie in a series of articles from 1897 to 1901.

[4] Proceedings of the International Congress at Copenhagen, 1884, Ophthalmic Section.

[5] Report of the Heidelberg Ophth. Society in Deutsche med. Wochenschrift, October 9th, 1884.

[6] Archiv f. Ophthalmologie, 1866, xii., p. 95.

[7] Archiv f. d. gesammte Physiologie, Bd. xxiv., p. 115.

EYE DISEASES. See under *Cataract, Choroid, Conjunctiva, Cornea, Glaucoma, Hypermetropia, Myopia,* etc.

EYE, INJURIES OF.—It will be proper, in writing on injuries of the eye, to take for granted that the reader is well acquainted with the anatomy and physiology of that organ, and such of its appendages and surroundings as, on account of structure, function, or situation, are likely, in case of injury, to require treatment differing in any way from that which would be suggested by the principles of general medicine and surgery.

It is understood, too, that the reader has acquired the art of using easily and well all the instruments and methods needed by the oculist for the diagnosis and treatment of those affections which are not traumatic. One requires, in handling cases of injury, not only to have at command an ophthalmoscope and a full case of surgical instruments, but to be well drilled in their use, and to possess also a certain adaptability to the situation and independence of thought and action, which will allow him to depart occasionally from conventionalities, and in emergency to use instruments for what they are worth, not necessarily for what they are made. For, though the results of violence may be routined off and classified as to the kind of operative interference that they may require, it is oftener in this branch than in any other that the surgeon will discover new and unprecedented situations or conditions which occur so infrequently as to have existed in literature only as forgotten curiosities.

Physical Conditions.—A word or two relative to the physical conditions which exist in the healthy eye may be of service in helping to appreciate those which are likely to exist in the injured organ, or in one in which inflammatory changes following injury have not been met by the necessary surgical interference.

The eye is a globe; it is filled with fluid, semifluid, or gelatinous matter which is practically incompressible. Its walls, though elastic and flexible, cannot be stretched very much, and as the sphere is that form which will contain the largest amount of matter within a given area of covering, the result is, there being no outlet, that if pressure is put upon this globe it will not change its shape very much without rupture. The physical conditions are very much the same as those of a leather ball filled with water—not those that exist in a rubber ball filled with air. The walls of this globe are very flexible, and when the globe itself is emptied any part of the sclerotic or cornea can be bent on itself like cloth. Neither of these tissues, either with or without its lining membrane, is subject to fracture in the true sense of the word, and when there is any complete and violent solution of continuity in these parts it is due either to laceration, to puncture, to cutting from some sharp substance, or to tension, erosion, or chemical action. The particular part at which rupture takes place will be the part at which the enveloping material is the weakest, unless, perchance, that part, at the time of the stress, is better supported by the pressure of neighboring parts, or unless some other portion is made comparatively weak by the pressure of some foreign substance which bends or indents it, and so places on it a local strain that cannot be transmitted. Rupture by contre-coup is not possible in the eye, though it is sometimes spoken of as having taken place.

Before considering each separate tissue in order, it may be well to supplement what has already been said by calling attention to the fact that the enclosing tunics of the healthy eye are more than full, and once their integrity is broken a small part of the contents is likely to be forced out by the elasticity of the tissues; that the secretion of aqueous and vitreous, and the supply of blood to the interior of the organ, keep its elastic covering always in a state of tension, and when, by rupture, cut, or puncture, or by ulceration, or decay of injured tissue, there is any solution of continuity, a part of the contents will have a tendency to escape; and while the opening remains, the constant building up of material to supply the place of what has been lost often forms a serious obstacle to the rapid healing of the wound, or the successful return of any part of its contents, such as protruding iris or vitreous, to the eye.

Without having at hand any experiments which may be quoted as giving definite knowledge of the actual strength of the materials used in the structure of the eye, it is possible to state, from records kept in cases of injury, that the part which is least capable of resisting strain put upon it by external pressure is the sclerotic, 3 or 4 mm. from the sclero-corneal margin. This is by far the most frequent seat of rupture, which nearly always takes place in a direction parallel to the sclero-corneal margin. The fact that it is usually found to have broken through the meridional fibres in the upper and inner quadrant is probably explained by the position of the surrounding parts, which are such as to protect it from external pressure, and yet to give little or no support when the eye is pressed upon from some other direction. The cornea rarely ruptures, and when it does, it is from some ragged extension of an irregular sclerotic tear, and is not to be looked upon as primarily a corneal lesion. The thickness of the sclerotic and cornea in the accompanying cut is not to show the actual size, but to indicate diagrammatically the relative liability of different parts to give way whenever, from any cause, sufficient pressure is put upon the eye itself to make a rupture of its tunics inevitable. In the same figure the choroid is drawn as if it were attached to the inner side of the sclera only at the nerve, at the venæ vorticosæ, and at the ciliary processes (Nos. 1, 2, 3). This is not really the fact, but it is so much more loosely attached at the intermediate points that, whenever the choroid itself ruptures—as it sometimes does if pressure so distorts the eye as to pull this membrane away from the overlying sclera—the break does not ordinarily occur at any of the three points named above, but at some intermediate place. Such ruptures are most frequently seen, of course, in the posterior part of the eye, often nearer the nerve than the equator. They also do occur anteriorly to the venæ vorticosæ, and sometimes so far forward as to be unrecognizable during

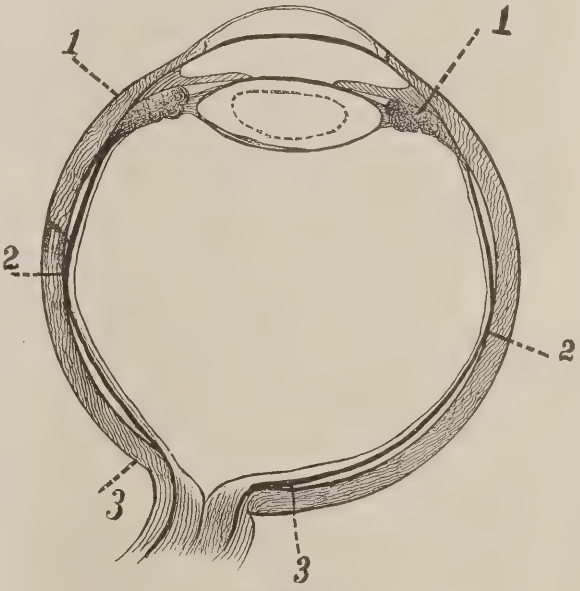

Fig. 2049.

life. The writer has seen one case in which history, symptoms, and ophthalmoscopic appearances warranted the diagnosis of rupture of choroid, with only this element of doubt in the case. The linear cicatrix which was in other respects so characteristic passed downward and inward about forty degrees from the vertical, directly across the head of the optic nerve, being visible up to the edge of the nerve above and reappearing at the edge of the choroid on the other side below.

The lens, in its capsule, and the suspensory ligament form rather an unsubstantial partition between the anterior and posterior chambers, and, while the outer tunics are intact, this structure is not very likely to be ruptured by any pressure which is uniformly distributed over the outside surface of that organ; but a distortion of the globe which tends to lengthen any diameter of the ciliary ring will do serious injury to this delicate structure, and a rupture of its walls in the immediate proximity of the lens or zonula so disturbs the equilibrium between the two chambers that dislocation is almost sure to follow. Quite often lens, iris, and zonula are all carried away by the pressure and expelled through the wound which has taken place in the stronger membranes.

The suspensory ligament is so delicate that it is said to have been ruptured by blows upon the head, which, not touching the eye at all, have caused the comparatively heavy lens to tear away its support by the rapid and violent vibrations thus imparted to it; though dislocations first discovered after such blows may be congenital.

It would be wrong to leave this subject without saying a word concerning the iris. The iris is one of the weakest muscles in the body, and the contractile tissue, which changes its size and shape so readily, is not able to do so against any appreciable resistance. In health it floats in the aqueous, attached only at the periphery in about the same manner that a delicate film of sea-weed exhibits its natural conformation in water, but collapses and loses its form when removed from that element. When the support of the lens is removed from behind it, it trembles with every movement. If there is a leak in the cornea in front of it, it is drawn into the opening, however slight, and unless extra precautions are taken it is sure to get in the way and interfere with the execution of any operation which is planned in the cavity that contains it.

It is well, of course, to know the strength as well as the weakness of different parts. The cornea is as deceptive in its strength as is the iris in its weakness. The reason that the amateur of the workshop so often fails to remove small foreign bodies which have stuck fast in the cornea is because he has been afraid to more than touch it for fear of penetration. This accident is much more likely to happen to the professional than to the amateur; but in view of the serious result of such accidents, it is well perhaps that the popular impressions be allowed to obtain. Still, though the cornea looks as fragile as a bubble, it will withstand considerable rough treatment from the hand of an expert. It is hard and almost ligamentous in its texture, and though extremely sensitive on the outside, is somewhere near 1 mm. in thickness.

EXAMINATION.—In examining an injured eye one must look at it as if he had never seen an eye before, and were going to find out just how it is made and what had been going on around it. Knowledge of what ought to be will call attention to what is. But injuries do not come tagged and labelled, and with hemorrhage, inflammatory swellings, lymph deposits, discoloration, and destruction of tissue, there is often as much difficulty in the diagnosis of injury as of disease. The lids should be pulled wide open and examined thoroughly for cuts, scars, perforations, and foreign bodies; neighboring cavities should be probed and foreign substances removed. One should look the cornea over at the window as he would examine any other lens for chips or scratches; he should also, by the aid of focal illumination at the gaslight, hunt for perforations, and should explore all depths of aqueous, lens, and vitreous by the lenses in the ophthalmoscope which will put them in and out of focus, being careful not to be so absorbed and interested in one injury that some other is overlooked and neglected.

Some readers of this HANDBOOK, who do not make or do not wish to make a special study of ophthalmology, will doubtless be called on for advice, and will feel obliged to assume the care of diseased and injured organs of sight until such cases can be transferred to other hands. The first lesson to be learned by those who are thus feeling their way is what not to do.

Cases may be divided into those which need astringents and those which need anodynes. There is one astringent that must never be used—it is acetate of lead. Useful as it might be in some cases, it is so dangerous to many corneal affections that it should never be given except by an oculist so proficient as to be able to ignore rules and indulge in ophthalmological jugglery; but by him it is seldom needed. There is one anodyne that excels all others—it is atropine. The cases which are injured by atropine when they need astringents are so few as to be counted on the fingers of one hand. The cases which are injured by astringents when they need atropine are very many; so, when in doubt, if you use atropine you will benefit half the cases and injure none, whereas the astringents blindly used will benefit half the cases and injure many. The fact that atropine is poisonous to swallow, while most astringents are much less so; that atropine blurs the sight, while astringents do not; that atropine is nearly always used in serious cases, astringents in those comparatively simple, leads the novice to hope for the best and use astringents where he would much better, if he feels himself at all off his ground, believe in the worst and use atropine. The cases in which atropine must not be used are easy to diagnose, with the exception of glaucomatous trouble, with which this paper has nothing to do. Atropine may be used with caution where there is perforation or rupture of the globe near the sclero-corneal margin. Its use is said to predispose to prolapse in such cases. In the writer's belief neither the physical conditions nor the results of experience tend to corroborate this view. Atropine, generally speaking, should not be used when a foreign body is lodged on the iris or is loose in the anterior chamber, and likely from slight disturbance to fall down behind the iris or behind that part of the sclera which forms the opaque peripheral front wall of the chamber. In most other injuries atropine is the one remedy which the surgeon cannot well dispense with, while astringents, though sometimes useful, are seldom indispensable in the treatment of recent injuries.

Arlt found it convenient to divide injuries into:

1. Those produced by sudden compression or concussion.

2. Those produced by foreign bodies not acting chemically: (*a*) Those in which the foreign substance does not remain in the eye; (*b*) those in which the foreign body does remain in the eye.

3. Those produced by scalds, burns, and corroding substances.

This is a classification which must naturally run through any attempt to consider this subject, whether from a medical or a mechanical standpoint.

HEMORRHAGE.—A word or two may be said in a general way concerning hemorrhages, which are not connected with any lesion more definite than the breaking of a blood-vessel, the location of which is often unknown. Conjunctival extravasations of blood, such as come from slight blows, or from straining, coughing, stooping, or any violent disturbance of the circulation or increase of the heart's action, are of no particular importance, and require no treatment; apart from their gorgeous coloring they would scarcely attract the attention even of the patient. The parts should be examined carefully, to make sure that there is no solution of continuity. Then, if there has been no impairment of vision, either peripheral or central, the patient may be assured of certain recovery.

Hemorrhage into the anterior chamber is almost always due to violence; it is rarely dependent upon scurvy or upon the presence of a neoplasm, and very rarely it has been reported due to other causes, such as menstrual or diathetic influence. The blood generally comes from the iris, and, unless the hemorrhage is caused by some dislocation or rupture other than that of the vessel's wall, is rapidly absorbed, sometimes disappearing within three days, sometimes remaining for as long a time as three weeks. When enough blood has been effused to conceal the inner structures of the eye, the diagnosis should be guarded, as they may have suffered serious injury.

Hemorrhage also takes place occasionally into the posterior chamber, leaving no trace of injury by which to account for the presence of blood. The ruptured vessels are supposed to be in the anterior extremity of the choroid. The depreciation of vision is often just as great as would attend choroidal rupture or other serious injury, so that it is impossible to tell at the time whether or not such injury has occurred. The treatment, of course, should be the same as that of the serious injuries which it sometimes accompanies and conceals, and it may not be possible, for six weeks or more, to say decidedly that no separation of retina or rupture of choroid has taken place near the posterior pole of the eye.

Commotio Retinæ.—After a blow on the eye, producing no other visible injury, vision may be reduced, the pupil becoming small and responding slowly to atropine while the retina is white and anæmic over the whole or a large part of its area. This condition reaches its height in about twenty-four hours and by the end of a week should be well on the way to recovery. The name, though given before the nature of the trouble was well understood, seems particularly well chosen, as the vitreous is violently forced into the region of the nerve fibres and other retinal layers are more or less affected. Such cases recover without treatment, but before allowing them to do so it is necessary to satisfy one's self that there is no rupture of the choroid or partial dislocation of the lens; that the amblyopia is not due to fracture of the skull at the optic foramen, to stretching of the zonula, or to paralysis of the accommodation.

Paralysis of Sphincter of Pupil and Ciliary Muscle.—Another injury which seems rather intangible, as far as its etiology is concerned, but which has actual existence, is the paralysis of accommodation, with partial or complete mydriasis, which sometimes follows a severe blow upon the eye. In mild cases recovery may be expected in a few days, but where the pupil is widely dilated and there is total loss of accommodative power, the patient does not recover. The indications, if any, are for the instillation of eserine.

Lids.—Passing now to those injuries in which actual damage has been done to the tissues themselves, I may simply remark, concerning the lids, that whatever may happen to them it is proper to treat the condition in accordance with the usual methods of general surgery, always remembering that they are much needed coverings for the eye itself, and when destroyed should be replaced at the expense of the surrounding tissue; care should also be taken to adjust the parts so that the contraction of the scars will not result in turning the lashes in upon the cornea or conjunctiva. Finally, it must not be forgotten that cuts across the edge of the lid margins are liable to gape and consequently they should be adjusted and supported during the healing process.

Conjunctiva.—Wounds—such as cuts, punctures, or tears—of the conjunctiva, unless they are inflicted by some instrument that causes contagion, and provided they do not involve other tissues, are not of a serious nature. They are amenable to the same treatment as is found effective in mild forms of conjunctivitis.

The extent of danger varies with the situation of the wound, the nature of the offending instrument, and the fitness of the system to undertake repair. In the first place, it is important to remember that even a slight cut in the conjunctiva of the lid may be the avenue through which some sharp instrument or foreign body has entered the orbit and has done serious injury to the optic nerve or the brain itself, a specially dangerous fracture of the orbital walls being produced by thrusts from sharp instruments which penetrate the upper part of the inner wall. Hence wounds near the peripheral part of the ocular conjunctiva should be closely examined, and evidence of foreign substances remaining in the wound or of serious injury to the orbit carefully weighed.

Small cuts or punctures limited to the conjunctiva are of little moment. The edges should be cleansed, sterilized, and freed from any particles of foreign matter that may still remain. Rest and cleanliness are the necessary conditions of recovery, and, though these wounds are not likely to be of an especially dangerous character, they demand some attention. The surgeon will often find it a difficult matter to decide just how far it is advisable to place restrictions upon the patient's usual manner of life. If wounds are comparatively large and the inflammation seems likely to affect the corneal tissues, or if there is any danger of serious results from the contraction of cicatricial tissue which may produce symblepharon, or ankyloblepharon, or entropion, or lachrymal obstruction, conjunctival wounds may be considered serious, and the patient should be made to consider recovery his first duty.

It may be necessary in some cases to put a stitch or two in the conjunctiva, to keep it in place until the healing process is established. Fine silk may be employed for this purpose, and usually it can be put in so lightly as to come out of its own accord when it is no longer needed. In putting in sutures about the eye it is very useful to have acquired sufficient dexterity to make the forceps take the place of one hand in tying the knot.

Should granulations spring up in or near the wound, they may be touched with nitrate of silver every other day. This and a one-per-cent. solution of alum for instillation will cause them to disappear.

If one of the recti muscles has been completely divided by a wound through the conjunctiva, the fact will be made manifest by an inability to move the eye toward the affected muscle, or by the occurrence of double vision, in which the image is displaced toward the injured side. The end of the muscle should be sought with a pair of fixation forceps and fixed in its proper place, as in the operation of bringing forward for strabismus.

The most serious wounds of the conjunctiva are, however, those which are made by burns from hot metals, acids, unslacked lime, and other irritating and corroding substances. The cornea is more than likely to be included, and upon the depth and extent of the corneal injury the final result is in great measure dependent. The principal danger, so far as the conjunctiva is concerned, is not so much the destruction of tissue as that, in healing, two surfaces which usually move freely over each other may become firmly united, causing symblepharon or ankyloblepharon, thus closing in part a cavity which should remain open. There is also the further danger that adhesions may take place between different parts of the conjunctival mucous surface of the lids, or between the lid and the cornea or some other part of the globe, and thus seriously lessen the mobility of the eye, or disfigure and inconvenience the patient by unsightly deformity or by the constant irritation of an organ so attached.

The first thing to be done in such cases is to remove the irritating substance, if it has not already been removed. Melted metal, which has cooled into place, must often be removed by the use of considerable force and with some mechanical injury to the parts. Lime and sand may be scraped carefully from the *cul-de-sac* with a Daviel's curette or spoon. It has been recommended that at the time of the accident alkalies should be washed from the eye with weak acids like vinegar, acids with weak alkalies like soda or salaratus; these remedies are usually at hand, and are chemically appropriate. But there is nothing so swift and appropriate as plenty of water, with which the eye may be flushed immediately. The fact that strong sulphuric acid and lime evolve heat and are more injurious when small measures of water are added does not count for much when water can be supplied in large quantities and without any delay.

These injuries, when the cornea is not implicated, call for quiet antiphlogistic treatment, with the instillation of sterilized olive oil, linseed oil, or vaseline, and of atropine to allay any irritation or tendency of the cornea or iris to become inflamed.

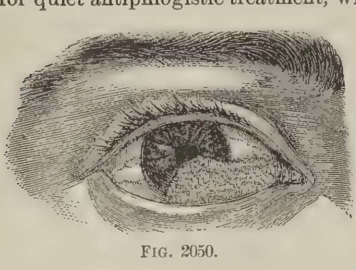
FIG. 2050.

If the injury is attended with much pain, cocaine should be used as often as necessary to secure the comfort of the patient. When the destruction of tissue extends so deeply in the *cul-de-sac* that there is no bridge, or only a narrow bridge of sound conjunctiva between the two injured parts, little or nothing can be done to prevent their growing together during the healing process. The opposed surfaces must be separated frequently, and in spite of this the contraction of cicatricial tissue will almost always bring them together as they heal, and will do this with persistency. Plates of wax, glass, silver, or gutta-percha may be worn for a while at some risk of irritating the eye, but in the course of time they will be crowded out, and are more likely to do harm than good. Attempts to improve the local conditions by resorting to surgical interference after the wound has entirely healed, are not likely to produce materially better results. Cutting the bridles and attachments affords only temporary relief, and it is only by the performance of a suitable plastic operation or by skin-grafting that we can hope occasionally to secure some measure of success.

If there is a free passage for a probe beneath the substance of the symblepharon, considerable improvement, or perhaps permanent relief, may be expected; but frequently the surgeon will exercise his ingenuity in vain. It may be put down as entirely improbable that any extensive symblepharon or ankyloblepharon which has grown up from the bottom of the *cul-de-sac*, will be greatly decreased in size by any of the measures mentioned.

The accompanying cuts are from Lawson, and represent very well the conditions indicated by the text. Fig. 2050 "represents the appearance produced by an injury to the eye from some fresh mortar, which was thrown into the eye the day before the boy was brought into the hospital." The coloring, of course, is not present, but the appearance of a burn caused by mortar is very characteristic. Fig. 2051 "is a good illustration of a case of partial ankyloblepharon, and shows very well the position of the fistula which is frequently met with when the inner portions of the lids are united." The particular case here pictured happens to have been the result of mechanical violence, but it may well have happened from either mechanical or chemical injury.

CORNEA.—Although the cornea is never ruptured by a blow or by pressure causing momentary increase of tension, and although it seldom suffers from any force transmitted to it through the closed lid (unless the lid itself is perforated), it often suffers severely from the impact of small bodies which have appreciable weight, and which so bruise without breaking its substance as to cause local death of the part struck. This results in the formation of what is known as corneal abscess. The abscess thus formed is, on account of the thinness of the membrane, not likely to exist as a sac filled with fluid of a purulent nature, but consists of tissue infiltrated with purulent matter which discharges itself either forward on the conjunctiva or backward into the anterior chamber, or more likely in both directions. This abscess may be of any extent, small or large; it may be superficial or it may involve the inner and deeper layers of the membrane. Its extent cannot be told at the time of the accident. The first sign of serious injury, apart from accompanying pain, is the conjunctival reddening and well-marked ciliary injection, which may extend entirely around the organ or may be confined to the immediate proximity of the part struck. Pain, photophobia, and lachrymation are naturally attendant on this condition, which may continue for two or three days before the grayish discoloration and opacity that follow the injury have marked out the seat and the limits of the destructive process. After this the disease follows the course of corneal abscess from any cause. Pus soon forms in the layers of the cornea and also in the anterior chamber, settling down to the lower part between the cornea and iris. By this time the inflammation will have advanced so far as to threaten the iris and ciliary region, and the pain is likely to be very severe. There is therefore danger that if the process is not checked by operative interference it may end in panophthalmitis. Pus at the bottom of the anterior chamber may be distinguished from that in the layers of the cornea by placing the patient on the side for a moment or two and witnessing the change of place caused by gravitation.

The treatment for corneal abscess of traumatic nature, either actual or threatened, is atropine, rest, and protection from the light. During the early stages, before the formation of pus has begun, cooling applications externally and iced compresses are likely to be of benefit. After suppuration is established, lukewarm or even hot water will be more gratefully borne and will probably hasten the progress of the disease toward recovery. Antiseptic precautions, of course, are necessary. They consist in frequent bathing with water of suitable temperature, to which four per cent. of boric acid has been added, or one-thirtieth of one per cent. of corrosive sublimate.

With pus in the anterior chamber and threatened or existing iritis or irido-cyclitis, it will often be necessary to administer morphine to relieve pain and to give the patient sufficient rest and comfort to insure the best recovery. Whatever the attitude of the patient is toward the use of this narcotic, it will be well to remember that pain is often worse than poison, and the surgeon should demand the right to choose.

If the pus at the bottom of the anterior chamber is more than 2 mm. in depth, or if the abscess takes on at its edge the halo of light gray, which indicates that the process at first due to traumatism is extending beyond the margin of the original injury, it may be necessary to evacuate the anterior chamber, and, perhaps, to open the abscess according to Saemisch's method, by passing a Graefe knife, which is held with its back to the pupil and iris, into the anterior chamber on one side of the abscess and out on the other, thus cutting entirely through the abscess from within outward. After this, the wound must be kept freely open until recovery is well established. This operation is not always necessary, paracentesis of the lower part of the cornea, in such a position as to favor the evacuation of pus from the anterior chamber, being often attended with the best results. This opening should be renewed at least every second day, until no pus remains.

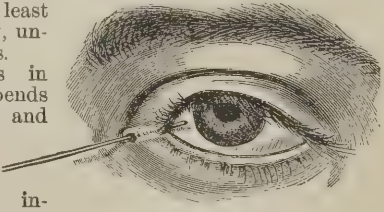
FIG. 2051.

The prognosis in these cases depends upon the extent and location of the abscess and the depth to which the tissues are involved. Wherever the abscess is, there will remain a white scar. This, of course, is of little importance if the scar is small and situated at the periphery; but if, on the other hand, it is situated in front of the pupil and is of such an extent as to obviate the possibility of making an artificial pupil, its presence will render the eye practically blind. If the abscess breaks externally, the lens or the iris is likely to rest against the wound and ultimately to become adherent to it, thus giving rise to unpleasant symptoms of irritation and inflammation, which may be well borne for many years, but which in some cases finally result in panophthalmitis and phthisis bulbi, or sometimes cause large and unsightly staphylomata. The usefulness of atropine and eserine in placing the iris in given positions should not be forgotten during the progress of the disease.

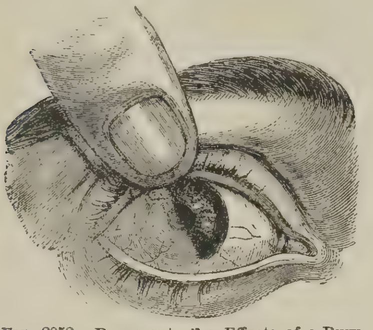

FIG. 2052.—Represents the Effects of a Burn from Molten Lead, that Splashed into the Eye from a Pot which the Patient was Carrying. (Lawson.)

Wounds of the cornea entailing solution of continuity may be mere superficial scratches, in which hardly more than epithelium has been removed, or they may penetrate the anterior chamber, injuring iris or lens, or extending to the deeper tissues of the eye. As the cornea is the principal lens in this physiological camera, the danger is twofold—that of its destruction as part of the firm enveloping membrane which holds the structures together, or that of distortion, deformity, or opacity, which destroys its usefulness as an optical instrument. If the wound is a mere superficial abrasion, complete recovery may be expected, though such injuries are often attended with great pain, neuralgic in its nature, with photophobia, lachrymation, and ciliary injection. The use of cold compresses, or of a bandage which keeps the eye closed and prevents the lid from rubbing up and down over the abraded surface, will allow it to heal in a few days, and the instillation of atropine, thrice daily, will banish the pain and hasten recovery. Occasionally, a slight abrasion made by some rough instrument, perhaps by the nail of an infant, on the cornea of its mother or nurse, will apparently heal within a few days, giving rise to no trouble at the time; but two or three weeks afterward, when the incident may have been entirely forgotten, severe and persistent neuralgic pains will call the surgeon's attention to a slight irregularity on the surface of the cornea, and with the instillation of atropine and a light bandage worn for a few days, the patient will entirely recover.

The prognosis for these wounds is favorable for the most part. Unless the loss of substance extends as deeply as the membrane of Descemet, there will be no visible scar, the transparency of the tissue remaining; but if the wound is at or near the centre of the organ, and not of a rather superficial nature, so much irregularity of surface will remain as materially to affect the eye as an organ of sight. Very slight injuries, such as those just considered, are often fraught with considerable danger to old people who are poorly nourished, or to those suffering from debilitating disease, such injuries taking the form of persistent and progressive ulceration, which is checked with difficulty. After the character of such trouble is established, it is no longer traumatic in its nature, and should be treated like any other similar ulceration.

When the cornea is penetrated by a clean, sharp instrument, which does not at the same time injure iris or lens, the wound, if not of large dimensions, may be expected to heal up quietly without any very great disturbance. The aqueous humor will, of course, be evacuated, except in very minute punctures; then, afterward, if the lips of the wound are adjusted by gentle pressure (preferably through the lid with a Daviel's curette), they will often unite by first intention, and allow the chamber to be re-established by the secretion of aqueous, which takes place very rapidly. Quite often, furthermore, the iris will not become attached to the wound against which at first it was pressing. Punctured wounds made by rough or blunt instruments often give rise to much more trouble. There is a larger vent for the escape of aqueous. The iris or the lens is likely to be pressed against the wound, or perhaps pushed through it. The healing process does not take place without some destruction of tissue and the formation of a white scar, to which either iris or lens or both may be permanently attached.

If the wound is seen at the outset, effort should be made to get the eye into something approaching its normal condition. Ragged edges of the wound or of the protruding iris, which cannot live, should be snipped off with the scissors. Gentle manipulations with Daviel's curette scoop or with the rubber spatula may cause the iris to return into the chamber. If it does not return, it should be excised, unless it has become adherent or seems to occupy a useful position in preventing the further escape of the contents of the anterior chamber. Should it be necessary to allow the iris to heal into the wound, or if later it becomes irritable, an iridectomy can be done to set the matter right.

Any wound which so opens the walls of the globe as to allow the escape of any appreciable part of its contents is a serious affair, and demands perfect quiet on the part of the patient—usually, indeed, the recumbent posture, especially during the early part of recovery. Next to rest, the most important thing, in corneal injuries, is to give frequent irrigations with normal salt solution or with some mild antiseptic solution (boric acid, for example). Avoid all depleting measures; allay pain with atropine or cocaine instillations, or with morphine subcutaneously if necessary to give the patient needed rest. If, after the healing process is well under way, there remains a fistula through which aqueous continually escapes, touch it with nitrate of silver, or burn it very slightly with the electro-cautery. It may be, and often is necessary, after recovery, to perform an iridectomy, for the purpose of affording relief from the irritating effects of iris attachments, or for that of making an artificial pupil.

Burns, scalds, and injuries of the cornea from irritating and corroding substances are of a more serious nature than similar accidents which affect only the conjunctiva; any deep destruction of tissue brought about in this way is followed by serious reactionary inflammation and resulting opacity. The danger of symblepharon is great in some cases, and should be guarded against as in conjunctival injuries. If the wound is seen immediately after the injury, it will in most cases give very little evidence of the amount of damage which has resulted or will result, but after the lapse of two or three days one can judge more accurately of the extent of this damage. Another word of warning should be given here against all collyria containing preparations of lead. Many cases, in which the eyes have been burned by acid or other corroding substance, have been made hopelessly blind by the use of acetate of lead collyria prescribed by some well-meaning apothecary who must needs do something in the emergency. The harmfulness of the lead preparations lies in the fact that they render all scars in the corneal tissue thoroughly opaque, and so interfere with the transmission of light to the retina.

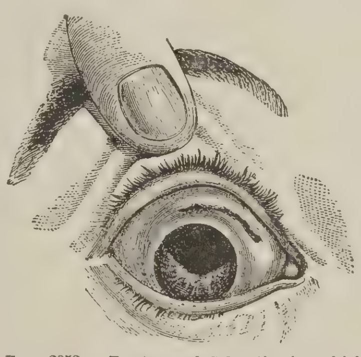

FIG. 2053.—Rupture of Sclerotic, in which Lens and Upper Half of Iris were Lost at the Time of the injury. (Lawson.)

Rupture of the sclerotic usually takes place upward and inward; the rent is from 6 to 12 mm. in length, and nearly always parallel to the sclero-corneal margin. It may also occur—though less frequently—in an outward or downward direction, and it may be irregular in shape, extending through the sclero-corneal margin. In rare cases rupture may occur in the posterior part of the globe. In that position it does not admit of positive diagnosis, but may be suspected in cases in which hæmophthalmus posterior is attended with very considerable decrease of tension.

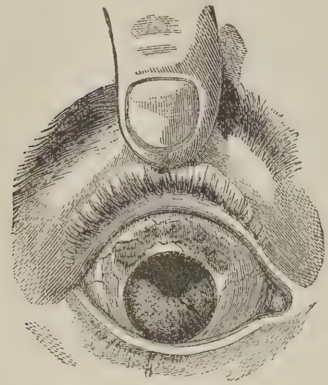

FIG. 2054.—Staphylomatous Appearance. Result of blow on the eye, which caused at the time rupture of sclera and dislocation of lens beneath the unbroken conjunctiva.

The complications which may exist are in great measure dependent on the force of the blow, and the extent to which iris, lens, or vitreous have been forced out at the time of the accident. Sometimes the lens is forcibly expelled, and may be found under the lid, or may be lost. Sometimes it may be seen at the seat of the rupture in a sac formed by the unbroken conjunctiva, where it (usually with a part of the iris) should be allowed to remain until the wound is healed and normal tension re-established. When this has taken place the iris may be removed through a suitable incision in the conjunctiva. Rupture of the sclera is usually attended by hemorrhage into the anterior chamber, often by prolapse of iris and escape of the lens.

Perfect rest is, of course, the first thing called for in the treatment of a rupture of the sclera. The patient should be confined to the room, and, if not kept in a recumbent posture, should avoid sudden movements or stooping, coughing, straining, which may lead to complications from hemorrhage into the choroid or to retinal separation. Iris or vitreous which protrudes from the wound may be removed with the scissors, if such interference can be borne without the administration of ether. If the lens is so situated as to prevent the lips of the wound from closing, or if it seems to press on the iris or the ciliary body, an attempt should be made to extract it. Atropine is usually indicated.

The prognosis in cases of rupture of the sclera is not so bad as one would be inclined to fear. Sometimes panophthalmitis, with its attendant train of destructive changes, supervenes; but often the usefulness of the eye is not entirely destroyed.

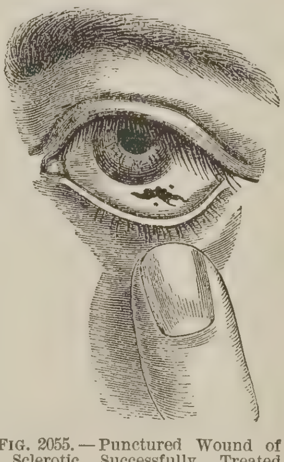

FIG. 2055.—Punctured Wound of Sclerotic Successfully Treated with a Fine Suture. (Lawson.)

Cuts and punctures in the ciliary region are almost sure to end disastrously so far as sight is concerned. The best result that can be expected is a quiet subsidence of the immediate inflammatory action, to be followed very likely by gradual cessation of function and partial atrophy of the tissues of the globe. Suppurative irido-choroiditis is very likely to follow any punctured wound of the sclera, even though it be situated so far back as to have escaped the ciliary region. It is not absolutely impossible that a clean cut through the sclera at the ciliary region, if made with a smooth, sharp instrument, may heal and leave a useful visual organ, but such a result is not to be expected.

The treatment for cut or punctured wounds is the same as for open ruptures. Tissues presenting themselves in the wound should be trimmed away as much as possible, without so disturbing the condition of affairs that more of the contents of the eye will be forced out to take the place of those removed. Gentle manipulation with the spatula or the scoop should be used in the attempt to leave the edges of the wound as nearly in their normal places as possible. If there is much gaping of the wound a very fine suture should be put in, if possible, through the outer edge of the sclera only; then both eyes should be kept closed and under gentle pressure. Even after the wound has healed and everything gives promise of a fair recovery, the contraction of cicatricial tissue may be the cause of retinal separations, followed or attended by gradual destruction of the wounded eye or by sympathetic trouble in the other.

IRIS.—Non-penetrating wounds of the globe are sometimes the cause of a rupture or a tear of the iris. Radiating rents and fissures are quite rare, and are not accompanied by any hemorrhage. The most frequent injury is a dialysis or separation of the peripheral portion from its attachment. This separation may be of almost any extent. It has been known to include so much of the membrane that it might be said to be entire, not enough of its ordinary support being left to retain any part of it in its normal position. The effect of a dialysis is usually to allow that part of the iris which is separated from its attachment to hang somewhat smoothly in the position of a chord to the arc which originally marked its place, so that both peripheral and pupillary margins are altered, as is seen in the accompanying cut, which is taken from Lawson. The kidney-shaped pupil is quite characteristic. This injury is often attended with considerable hemorrhage into the anterior chamber, which is of no particular moment and rapidly undergoes absorption. Beyond keeping the patient quiet, little or no treatment is necessary. Active inflammation very seldom follows the injury, and the harm that results, apart from cosmetic effect, is principally optical, due to the presence of two pupils instead of one. The patient either suffers from monocular diplopia or from an indistinctness of sight, due to the entrance of light into the eye without passing through that part of the lens which is capable of forming a distinct image.

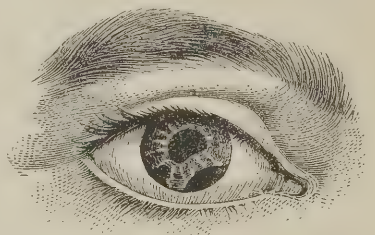

FIG. 2056.

It has seldom been thought worth while to attempt any operative correction other than an iridectomy to remove any portion of the membrane which interferes with visual ability by hanging directly across the optical axis. An iridectomy should be performed only when time enough has elapsed after the accident to prevent any unusual tendency to inflammation.

Cuts and punctured wounds of the iris occur concomitantly with the injuries of the cornea or sclera, and require no special treatment other than what has already been mentioned in connection with those injuries.

LENS AND ZONULA.—The position occupied by the lens and zonula may be represented by a circle formed by the intersection of the walls of the globe with a plane which cuts the visual axis at right angles, a few millimetres behind the iris.

A blow or pressure which causes the globe to depart momentarily from its approximately spherical shape, is likely to lengthen any one of the diameters of this circle and stretch or tear the zonula or the capsule containing the lens. And further, any pressure on the anterior part of the globe which increases the tension of the walls of the anterior chamber is likely to throw the lens backward, because the larger area of the walls of the posterior chamber allows of a greater increase of capacity before the same tension is reached. A bulging backward of lens and zonula is therefore likely to follow, so that each and every diameter of the circle in which they lie is increased in length.

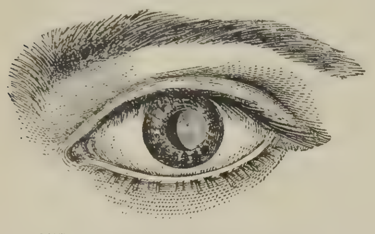

FIG. 2057.—Partial Dislocation of Lens which is Becoming Cloudy. (Lawson.)

One of these two conditions has probably existed in most of those injuries in which the only organic disturbance is a partial or total dislocation of the lens, either with or without rupture of the capsule.

It is said also that a severe blow on the head will cause such shaking or oscillating of the comparatively heavy lens as to tear the delicate membrane which suspends it between the fluid and semi-fluid humors. It seems almost necessary to allow this if we wish to account for certain dislocations that are reported—those, for instance, in which the eye itself has not been touched by the body inflicting the blow.

The disturbance that takes place in all these cases varies greatly, from the slight displacement forward which indicates a mere stretching of the ligament, to an entire breaking away from its support on all sides, so that the lens is thrown back into the vitreous, and sinks eventually to the bottom of the eye, or so that it is forced forward entirely through the pupil and lies entirely in front of the iris. Occasionally the lens is pushed a part of the way through the pupil, or it is pushed so that it comes to lie a little to one side behind the iris, in which position its edge may be seen across the centre. Under these circumstances the fundus is visible clearly with a minus glass if the observer looks through that part of the lens which is in sight, or with a strong convex glass if he looks at it through that part of the pupil from which the lens has been removed. Whenever the edge of the lens is in sight, if brilliantly illuminated, it may be recognized by a thin meniscus of vividly contrasted light and dark, caused by refraction and total reflection at the edge where the front and back surfaces curve round to meet each other.

Where the suspensory ligament is torn, the lens, of course, is left free to assume the convexity natural to extreme accommodation. Hence one of the symptoms of subluxation is (in the emmetropic eye) apparent myopia with entire loss of accommodation, and amblyopia, which latter may be due in part to astigmatism. If the lens has been moved backward and to one side, so that it only partially covers the pupil, monocular diplopia may be present; and if it is entirely removed from its place, as when it has fallen back toward the bottom of the vitreous humor, an apparent hypermetropia of somewhere near eleven diopters will be found; and on looking at a reflection of the candle flame in the eye, only that image which is due to reflection from the corneal surface will be seen. The two fainter pictures which are reflected from the anterior and the posterior lens surfaces will, of course, be wanting. A tremulous iris calls attention to the fact that its pupillary border has been deprived of the support usually given it by the anterior surface of the lens; still this symptom is not pathognomonic.

Partial dislocations of the lens backward are likely to become complete in time, that body finally sinking down to the bottom of the posterior chamber, and remaining there, after undergoing partial atrophy, for years—perhaps the least dangerous foreign body that can exist in that place. The eye is subject to the same inconveniences and accidents as were entailed by the old operation of couching.

In all posterior dislocations, unless there is some cogent reason for extracting, such as ciliary irritation or threatened sympathetic, it will be best to leave the lens as it is and make no attempt at removal. But if it presses forward on the iris, or has partly or wholly passed through the pupil and remains immediately behind the cornea, it should be removed as soon as the chemosis that immediately follows the accident has disappeared. The danger of attempting to remove a dislocated lens from the posterior chamber is very considerable. The cut is made of course as if for the operation for cataract, but the lens will rarely present itself on pressure, and recourse must be had to the spoon or the hook, and then, even when the utmost care is exercised, the lens will sometimes sink into the vitreous, where it cannot be recovered, or its extraction will be accomplished only with the loss of vitreous and perhaps subsequent accidents of hemorrhage and retinal separation.

If a dislocated lens is allowed to remain in the anterior chamber it gradually diminishes in size and sinks to the bottom of that cavity, where it remains in a shrunken opaque condition, and usually causes deterioration and opacity in the part of the cornea on which it rests.

When the lens is injured by a penetrating wound the cornea, or possibly the sclera, must of necessity have been punctured, and injury of the iris and ciliary body may also have taken place at the same time. Apart from the danger of these accompanying wounds, which of themselves may or may not be of a serious nature, there is every reason to expect serious trouble with the crystalline body. Any cut or puncture of the anterior capsule which brings the substance of the lens proper in contact with the aqueous humor is followed by an opacity and a swelling in that body, conditions which seriously interfere with nutritive and functional processes. Such an accident is much less serious in a child than in an adult, the softness and solubility of lens substance being such in the child as to admit of its somewhat rapid disintegration and absorption. These changes may take place so quickly and completely as to produce no serious injury other than the loss of the lens itself; or there may remain a capsular opacity which can be removed by any of the methods usually employed after the operation for cataract.

If much of the lens surface has been exposed by the opening of the capsule the swelling will be greater, there will be an increase of tension in the globe, and the pressure of the lens on the iris will cause a greater degree of irritation. If the patient has reached, or is nearing, adult life, the reaction caused by this disturbance will be quite severe, usually dangerous, and the result, so far as disappearance of the lens is concerned, will in no way be complete.

The closure of the capsular wound in such injuries is an impossibility. The indications are for temporizing and antiphlogistic treatment. Atropine should at once be given to prevent anterior synechiæ. Iritis and cyclitis should be combated with anodynes, and if the pain is severe, ice-cold applications should be added to the latter. Extraction should not be attempted unless the lens or a greater part of it has found its way into the anterior chamber. If the iris is pushed forward by the swollen lens and the symptoms are dangerously severe, the anterior chamber may be tapped repeatedly to allow the escape of aqueous and of any softened lens matter which has found its way into it; and in this way the process may be allowed to go on until sufficient absorption has taken place to permit the organ to return to its natural quiet.

After all inflammatory symptoms have subsided, if nothing but opaque capsule is left it may be operated on as before suggested; but if the rent in the capsule has been closed by a false membrane and there are considerable nucleous and cortical remains, these may be removed as in cataract operation, discission being the method which promises the best results, especially in children. It is very important to delay such operations until all danger of inflammatory reaction has passed away. The processes above described will seldom be completed in less than two or three months, and during this time the patient should be kept constantly under the care of the surgeon, and during convalescence he should wear shaded glasses. In spite of every precaution many cases of injury to the lens are not likely to end happily either for the patient or for the surgeon. Capsular inflammation is likely to block up the pupil with a dense membrane to which the iris becomes strongly fastened; pus also may show itself in the anterior chamber; and, finally, there may be panophthalmitis with complete destruction of the affected eye.

The Choroid.—The choroid is often ruptured as the result of sudden compression. The rent may occur at a point so far forward as not to admit of diagnosis during life, and from such accidents no doubt come many of the cases of hæmophthalmus posterior which make a fair recovery without any special mark to indicate the source of the hemorrhage. These anterior ruptures also are supposed to account for some of the hypothetical cases of commotio retinæ. Though ruptures are sometimes seen at a point anterior to the venæ vorticosæ, most of those which fall under surgical observation are near the posterior pole of the eye. They do not come at a point directly opposite the blow or pressure which causes them, but are situated on the same side of a vertical plane which passes through the centre of the globe from front to back. This seems to be in accordance with *a priori* reasoning concerning ruptures. The choroid has been known to rupture in two places at once, both ruptures being situated in the same meridian and on the same side of the eye as the compression which caused them.

Very often the perception of light becomes quantitative as soon as the accident happens, but sometimes the diminution of vision is not very great until after several days have elapsed. However this may be, the power of accommodation is at once suspended, and after recovery vision rarely reaches its normal acuteness. The wound, when first examined, will be found—if there has been no very great hemorrhage—to be filled with blood which conceals its edges. The uninjured retinal vessels may sometimes be traced over the wound; at other times the retina is broken through and separated at its edges from the choroid. The indications for treatment are the same as in other ruptures of the external tunics, except that constant recumbency is not so imperative and the patient may be allowed a little more freedom after the first few days. The inflammatory disturbance that follows rupture of the choroid, though sometimes destructive, is not usually very severe, and the amount of useful vision that is recovered is dependent very much on the seat of the lesion. Of course, if the tear has extended through the macula there will be a permanent central scotoma. The size of the final scotoma is not always commensurate with that of the original injury, it being sometimes much less than would have been thought probable.

Foreign Bodies.—Concerning foreign bodies in general, that have entered the eye and remained in it, a word or two is necessary. The eye is never safe so long as they remain imprisoned in its tissues. Still there is hardly any place inside its walls where, according to reported cases, foreign bodies have not remained for months and years. But in all, or nearly all, the cases so reported serious trouble eventually developed and brought the patient to the oculist. Yet it is fair to suppose that patients have sometimes carried foreign bodies in their eyes to the grave without serious trouble, but this is so exceedingly rare that in general, when a foreign body has penetrated the globe, it is good surgery to remove it as soon as the diagnosis is made; and if it is not possible to remove it from the eye, then it should be removed with the eye.

This rule admits of one or two exceptional cases, to be mentioned hereafter—cases in which foreign bodies, on account of the slight inconvenience which they cause at the time, invite delay for the purpose of escaping for a time the reaction which is sure to follow operative interference. Temporizing may be allowed only when the success of operative interference is not compromised by delay.

An investigation of the cases in which the globe of the eye has been penetrated by a foreign body and no attempt has been made to remove it, shows that in not a few instances the patient has experienced months of suffering and danger, and then finally has lost the sight of one eye, if not of both. Under these circumstances the surgeon should advise against a protracted postponement of operative interference. In a few cases only is it permissible to advocate delay. Thus, for example, if a patient presents himself having in the lens, or on the iris or retina, a small bit of copper or steel, an eyelash, or other substance which has been forced through to its position without exciting any lasting reaction, and if the eye has retained its usefulness in great measure, it is not necessary to attempt to remove it if it is so fastened in its position that any ordinary accident or change in the surrounding tissue is unlikely to make it at some future time more difficult of access. If it is so situated that to remove it is an easy and safe procedure, it would of course be the part of wisdom to do so without further delay. But if, as is often the case, it is where it can be reached only by operative interference attended with great risk of injury or failure, it is better to counsel delay, while giving the patient emphatic warning that when any change for the worse does occur operative interference will then become imperative. Ciliary injection, pain, tenderness, photophobia, or lachrymation, or any of the symptoms of beginning iridochoroiditis, should warn both surgeon and patient that further delay is dangerous.

The Use of Magnets in Removing Foreign Bodies.—Quite a large per cent. of the foreign bodies that penetrate the globe and would remain there but for surgical interference are made of iron or steel and may be removed more easily by the magnet than in any other way. Even if the magnet itself is not all-sufficient for this purpose, it may be of great assistance by adding magnetic attraction to the force applied by the surgeon to any steel instrument that he may employ.

For purposes of diagnosis the electro-magnet is especially useful. Definite sensations of pain in the eye as the circuit is made or broken furnish undoubted evidence of the presence of a magnetic metal. It must be added that the lack of such sensations does not with like certainty determine its absence.

There are three classes of magnets in use. The permanent magnet of Gruening is independent of batteries or electrical connections, and has proved to be a useful instrument. More powerful than this is the electro-magnet introduced by Hirschberg. Various forms of this are in use, most of them from five to eight inches in length and capable of developing an attractive force of considerable strength, even across the whole diameter of the eye. A giant form of this very valuable instrument has been constructed by Haab. This new instrument so enlarges its sphere of usefulness that it has become a well recognized part of the equipment of the hospital operating room. The fact that in its most desirable form it takes up a square metre of floor space, weighs nearly 200 kgm., and costs relatively a large sum, has somewhat interfered with its general adoption as an office accessory.

The methods of using the magnet are such as are naturally suggested by the situation. Various forms of tips are easily attached to the iron core; some being intended for insertion into the eye, others for placing on or near its surface. The greater the mass of the magnetic metal and the nearer the foreign body, the better. It should be remembered that although the attractive force is practically instantaneous in its action, the movement of the attracted body is not.

Viscosity and other structural conditions of the tissue are such that repeated attempts to extract a hypothetical foreign body on several successive days may give no evidence of its existence, and yet, on a subsequent repetition of the attempt, the body in question will appear.

The presence of a foreign body in the eye is so serious a matter, and the immediate results of extraction by means of the magnet are so brilliant, that one may easily overestimate the average benefit to be expected. It is to be remembered that many of the cases in which a foreign body has been removed from the eye without infection or undue violence, turn out badly, ending in atrophy or other serious trouble. Notwithstanding all this the magnet is a very valuable addition to the surgical outfit.

Foreign bodies that find their way between the lids, and stick fast in the conjunctiva without deeply penetrating it, seldom give rise to any trouble after they are discovered. If they are not easily seen by everting the lids under good illumination, it may be on account of their minute size, or because they have been carried up to the fold of transition beneath the upper lid. Particles of glass are particularly apt to escape observation. Focal illumination and a careful exploration with a Daviel spoon is all that is needed for their recovery, and this is easily managed unless there is considerable spasm of the orbicularis, when it may be necessary to anæsthetize the eye with cocaine, or possibly, in children, to resort to general anæsthesia. The seat of injury should be carefully examined to see that nothing has penetrated beyond the limit of the conjunctiva and has become lodged in the orbit or sclera.

Foreign bodies most frequently encountered in practice are those which have lodged in the substance of the cornea. They are sometimes very small and difficult to see, on account of their color being such as to harmonize with that of the pupil or iris. They can be detected readily in the direct light of the window, or by focal illumination, and can be removed nearly always without the aid of a magnifying glass. The point of a discission needle, cataract knife, or any other sharp instrument will be found useful for the purpose. The patient should sit or stand before the window and fix the eye on some object which will insure its being held in the right position, while the surgeon stands wherever the substance can be most distinctly seen. Some patients will fix better by looking with both eyes, others with only the injured one.

It is not always possible to pick up a small particle of steel or emery on the point of a needle until after repeated efforts. In order to diminish the pain caused by such efforts it is a good plan to scrape off the epithelium from the very small surface (less than a millimetre in diameter) immediately surrounding the foreign body. When these small substances have penetrated deeply into the cornea, great care should be taken not to push them through into the anterior chamber. Such an accident is of a most serious nature; it is quite likely to necessitate an iridectomy for the removal of the foreign body. When the foreign body is so deeply situated that this accident seems imminent, it is best to enter the anterior chamber with a Graefe knife, which should be introduced at a point 2 or 3 mm. to one side of the foreign body and made to emerge at some distance beyond it. The flat of the knife will thus serve as a support for the foreign body, which may then be removed with safety by the usual manipulations. Care should be taken not to turn the knife so as to allow the escape of aqueous and not to encroach any more than is necessary on the pupillary area. Sometimes a splinter penetrates the layers of the cornea and seems to be placed lengthwise in its substance in such a manner that it can neither be removed by forceps nor grasped by a needle. In such a case, the upper layers of the cornea may be opened by a Graefe or a Beers knife, held with its back to the anterior chamber. In rare cases a small bit of foreign substance may be driven through the cornea in such a manner that one end of it hangs loose in the anterior chamber, while the other remains fast in the deeper layers of the cornea. When this state of affairs exists, the foreign substance may be removed by making a cut in another part and removing the offending substance from within with a pair of delicate forceps.

Foreign bodies in the anterior chamber, unattached to the iris or lens, often sink to the lower part of the sclerotic border. Very small bodies may be concealed there or behind the iris or the opaque sclera. They sometimes become partly encapsulated or surrounded with lymph before exciting destructive inflammation. In some cases they may be removed by an iridectomy. Occasionally such a foreign body has ulcerated through and has been discharged before the eye was entirely ruined. If such a process is going on when the patient first presents himself, it may be well to temporize, but never to delay operating with the hope that the substance may be gotten rid of through the establishment of such a process.

In cases in which it is otherwise impossible to diagnose or localize a foreign body it may often be seen by the aid of an "*x*-ray" apparatus and a fluorescent screen. Two pictorial reproductions from different positions are usually necessary and sufficient to determine, with some degree of exactness, the position of the foreign body. This is done by comparing its position in the picture with that of other substances, which though outside of the eye have been placed in the field in a manner suitable for comparison.

Lens and iris seem particularly tolerant of foreign bodies. If a small foreign body is attached to the iris in such a manner that it does not seem likely to fall to the bottom of the anterior chamber, it may be left *in situ* as long as it causes no disturbance, provided the chance of successful removal is not growing less. A foreign body in the lens, if the opening in the capsule is small, may be left in place until it can be successfully removed by a cataract operation. If the capsule is widely opened, the case should be treated as a traumatic cataract, and the foreign body should be removed if possible with the swollen cortical.

A foreign body in the vitreous, immediately behind the lens, will sometimes present itself at the wound and be expelled by gentle pressure, or it may be removed by a scoop or hook, after the lens has been removed by a cataract operation. Such a result, though gratifying, is hardly to be depended on. In fact, the removal of a foreign body from anywhere in the vitreous is something of a forlorn hope. An incision either equatorial or meridional, may be made back of the ciliary region, and in such a manner as not to divide entirely any of the muscles. Through this opening the foreign body may come, or may be made to come. A few cases have been recorded, but no one has had so many, or has been so successful, as to warrant us in establishing any rule or definite course of action.

When a foreign substance has been in the eye so long as to cause considerable inflammation, which has rendered the vitreous opaque and full of connective-tissue opacities, removal is out of the question as a means of preserving sight, and a constant watch should be kept over the patient, so that the globe itself may be enucleated before the establishment of severe or dangerous inflammation. Small substances (less than 2 mm. in their longest diameter) that rest on the retina, or are suspended in the vitreous, do not demand surgical interference if, when they are first seen, the symptoms of irritation have passed away, and if delay in removing them does not seem likely to render the operation more difficult.

Foreign bodies, both large and small, may pass through the conjunctiva and remain in the orbit. If their presence is not recognized at the time, the external wound is quite likely to heal. In rare cases the body then becomes encysted, but more commonly it gives rise to orbital abscess, and is discharged or removed with the contents of the abscess. Orbital abscesses are not unattended with serious danger, on account of possible pressure on the globe or extension to the cerebral cavity.

William S. Dennett.

EYE, TUMORS OF.—I. TUMORS OF THE EYELIDS.

A. *Benign Tumors.*—The benign tumors of the lids are partly congenital, partly acquired later on in life Their growth is but seldom accompanied by any inflammatory symptoms. These tumors, of course, during their growth, are influenced by the nature of the tissue from which they spring and into which they grow, and the variety of tissues which constitute what we term the eyelids necessarily brings about a number of distinct forms of tumors, and an endless variety in their shape.

1. *Warts* and *epithelial horns* (not to be confounded with epithelial growths) are sometimes found on the outer dermoid surface of the lids, more frequently on the upper lid. They may be congenital, and they may keep on growing gradually until it becomes necessary to remove them on account of their unsightliness, or because their weight is felt disagreeably and has become a hindrance to the free movements of the lids; or, finally, because they actually obstruct sight by obscuring a part of the visual field in certain positions of the eyeball.

Such warts usually spring from the lid, with a broad basis. They are not easily confounded with epithelial growths, because they lack a zone of inflammation and infiltration, which, in the case of the latter, is never wanting. Furthermore, epithelial growths usually show points of ulceration. Moreover, epithelial growths of the eyelids, although observed in young subjects, are more frequently found in the declining years of life, and lie most frequently near one of the canthi or at the lid margin. Warts and horns, however, are found in all ages, and seem to be more frequent near the middle portion of the eyelids than at any other locality.

According to their superficial arrangement, such epithelial warts of the eyelids have been described as papillomata when resembling cauliflower, and as condylomata when resembling the broad or pointed condylomata observed in other regions of the body.

The histological structure of these warts has nothing that would distinguish them from other warts of the skin. They consist of hypertrophic papillary structures, covered by very thick and horny layers of epithelial cells.

Although such warts are in themselves benign tumors, we must state here that in later years epithelial growths often begin from such warts, and their removal is therefore to be recommended.

2. *Granuloma* or *chalazion* of the eyelid is, in contradistinction to the other benign tumors of the eyelids, an inflammatory tumor. In its origin it is a hordeolum, that is, an inflammatory process caused, in the more superficial or the deeper layers of the eyelid, by the stoppage of one or more secretory canals of the Meibomian glands, be this merely mechanical (by foreign substances) or due to an infection or an inflammatory process, which only secondarily involves the secretory ducts of these glands. Such a Meibomian hordeolum is originally the distended Meibomian gland, filled with its own secretion and pus, and later on with an atheromatous detritus. This sac, so to speak, lies, as is clear from its mode of development, embedded within the tarsal tissue, and pushes out the skin of the lid in the form of a roundish elevation, the periphery of which falls off into the surrounding tissue at a more or less acute angle. These tumors vary considerably in size, and, aside from the deformity which their presence causes, they may have to be removed because they interfere with sight.

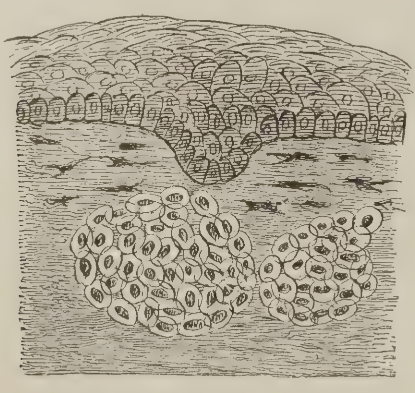

FIG. 2058.—Xanthelasma of the Eyelid.

We find, then, usually, that these tumors (tarsal tumors, as they are often styled) consist, at a later period, to a great extent, or even totally, of granulation tissue, which, having sprung from the walls of the sac, has forced the semifluid contents of the original cyst to one side where they have undergone partial absorption. Later yet, we may find solid granulomata, and no vestige of the atheromatous or purulent contents of the sac. As curiosities we may mention that one author claims that chalazion is due to the tubercle bacillus, while another author has even found an enormous bacillus chalazicus.

This is undoubtedly the form of tumor most frequently met with on the eyelids.

3. *Xanthelasma* or *xanthoma* of the eyelids is not a rare affection. It seems, however, to be more frequent among females than among males. It is a roundish or lobulated elevation of the skin, of a peculiar yellowish appearance, which has given it its name. Its development has often been brought into relationship with diseases of the liver.

Very frequently these elevations occupy symmetrical positions on both eyes, especially on the upper eyelids. They are not found in early youth, and undoubtedly belong to the later years of life. In females they often develop in the catamenial years. Aside from the deformity which they cause, there is hardly any reason for their removal.

So far as their histological formation is concerned there can be no doubt that different forms of tumors which have nothing in common except their yellow aspect, may be taken for xanthelasmata. This yellow coloring is due to the presence, in the subcutaneous tissue, of a large number of stellate connective-tissue cells which contain yellow pigment granules. Aside from these, the tumor may consist of connective tissue which has undergone fatty infiltration and degeneration, or it may show plainly a hypertrophic condition of the sebaceous glands, with stoppage and perfect occlusion of their excretory canals. We find then, in these tumors, large, round sacs of connective tissue filled with the enormously swollen epithelial cells of these glands, which are undergoing retrogressive metamorphoses (see Fig. 2058). In other cases we find simply a dense connective tissue, void of even a trace of the glandular structure, but containing the pigmented, stellate cells which these tumors all have in common, and from which they derive their name. The same enlarged and degenerated epithelial cells are found in molluscum contagiosum and have been claimed to be the characteristic molluscum bodies. They are, however, also found in epithelial horns and other pathological conditions of the lids.

According to their form, these tumors have been described as xanthelasma planum or tuberosum.

4. *Angiomata* of the eyelids are almost always congenital tumors, although, from their slow development, they may become noticeable only several years after birth. They belong either to the cavernous or the arterial variety.

The cavernous angiomata cause a swelling of the lid in which they are embedded, and usually impart to it a dark-blue color. If the upper lid be the one affected, it cannot be raised freely, or else it shows the condition known as ptosis. Any impediment to the continuous flow of the venous blood (stooping down, coughing, pressure, etc.) causes the tumor to swell. These growths frequently extend backward into the tissues of the orbit, or into the tissues surrounding this cavity. From their site, color, and conformation, such cavernous angiomata may be, in rare cases, confounded with orbital cysts, which sometimes cause a very similar aspect of these regions.

The histological structure of these cavernous growths shows, of course, nothing peculiar.

The teleangiectatic tumors are usually smaller than the cavernous ones, and since they generally reach to the cutaneous surface, they are recognized at a much earlier period. There is very often but little or no swelling, but the bright-red, enlarged blood-vessels can be seen through, or even in, the skin. This kind of angioma is but seldom confined to the eyelid alone. Yet there are also teleangiectatic tumors of the eyelids so well defined that they can almost be enucleated like a granuloma.

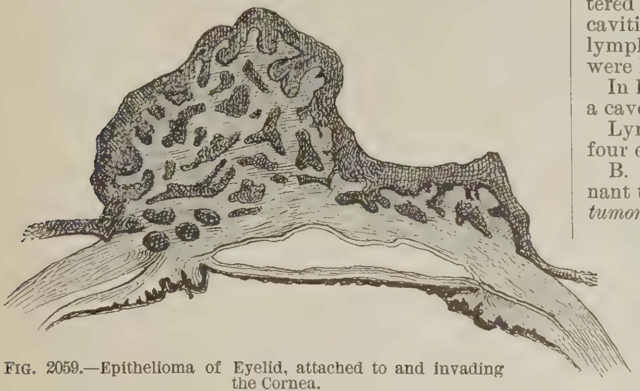

FIG. 2059.—Epithelioma of Eyelid, attached to and invading the Cornea.

While cavernous angiomata are apt to grow with advancing years, the teleangiectatic angiomata do not seem to have this tendency to a very marked degree.

5. *Fibromata.—a. Hard fibromata* of the eyelids are of very rare occurrence, and may possibly take their origin from a granuloma formed in the cystic distention of a Meibomian gland (hordeolum). The writer has seen and examined only two such cases. In both, the round tumor was implanted in the tarsal tissue, and raised the skin of the lid just as a chalazion does. In both, the tumor was situated in the upper lid and was harder to the touch than a chalazion usually is. The size of the tumors was about that of a cherry pit, and they consisted altogether of a dense connective tissue with short spindle cells.

β. The *soft fibroma* (fibroma molluscum) of the eyelids is also of very rare occurrence, and is usually found at the same time on other parts of the body.

These tumors, which appear always in large numbers, vary in size from that of a pea to that of a large pear, and even much larger ones have been observed. As they grow they usually become pedunculated, and hang pouch-like by this pedicle.

Their histological structure has not as yet been satisfactorily studied. Some authors have found only soft connective tissue, while others report the presence of peculiar cells undergoing retrogressive metamorphoses—probably epithelial cells of the sebaceous glands, resembling closely those found in xanthelasma.

γ. A third form of *fibroma* of the eyelid has been described as *plexiform neuro-fibroma.* This rare kind of growth is said to be congenital, and to consist of a series of swellings and cords which lie in the subcutaneous tissue, and which in parts are extremely painful to the touch.

The histological examination has not cleared up the nature of these fibromata very materially. They are said to consist of dense connective tissue, rich in nuclei, and surrounding simply atrophic nerve bands, or nerve fibres undergoing fatty degeneration.

6. *Lipomata* of the eyelids are of rare occurrence. They may be congenital, or they may appear in very obese people in advanced life. In the latter case they are apt to grow, and may have to be removed because they interfere with the sight, and this is especially apt to be the case when they develop in the upper lids and hang over the lid margin.

No further importance is attached to this kind of growth.

7. *Lymphangiomata* and *lymphomata* have also been found in the eyelids.

The case reported as lymphangioma seems to be unique. It is said to have been situated at the lid margin, the size being that of a split pea. It consisted of fibrous connective tissue, throughout which were scattered a large number of cavities of different sizes. These cavities contained a fine, granular substance in which lymph cells were suspended. The walls of the cavities were lined with an endothelium.

In harmony with this description the tumor was styled a cavernous lymphangioma.

Lymphomata of a very large size were found in all the four eyelids of a man suffering from leukæmia.

B. *Malignant Tumors of the Eyelids.*—1. Of the malignant tumors of the eyelids the most frequent are *epithelial tumors,* and among them especially the flat epithelioma.

The epithelioma of the eyelid begins almost always at the lid margin, especially on the lower lid, and it seems to grow with preference near the inner or outer canthus.

In the beginning we usually find a small, roundish, reddish nodule, which is quite hard. Sometimes this hardness and some redness around the original nodule are the only symptoms by which we may distinguish it from a common wart. After a while, either spontaneously or because the patient keeps irritating it with his fingers, the surface of this nodule becomes slightly ulcerated, and a crust is formed. Now this one nodule may keep on growing and spreading, and become excoriated at its surface, or new nodules may spring up around it and share the same fate. Thus there is finally developed a flat ulcer, with a hard base, and hard, ragged edges, which frequently bleed profusely when but slightly injured. As the ulcer creeps along some parts may heal, and the tough white bands of scar tissue give the affection then an aspect very similar to that of scirrhous cancer in other parts of the body. The infiltration of the tissues, the breaking down of the lid margin, and the development of bands of cicatricial tissue—all these alterations, singly or combined, may cause very annoying and unsightly deformities of the eyelids. The lower lid, as a rule, becomes everted, and to all other afflictions is added a continuous flow of tears. The growth of this kind of epithelioma is but slow and, *quoad vitam,* very much less to be dreaded than another form of this growth which eats rapidly into the tissues and breaks them down in a very short period. In the latter variety the rapid progress of the primary disease is soon followed by infiltration of the lymphatic glands and of the parotid, or the disease may spread over the conjunctiva bulbi into the cornea, and, eating its way through it, may enter the eyeball, or grow around it and invade the tissue of the orbit. This form is, luckily, observed rarely, and the prevalent form is the one which we first described.

Epithelioma of the lid is a disease which is found in individuals of advanced age only.

When this form of tumor involves the eyelid the histological elements found are precisely the same as those observed in the growth when it involves some other part of the body. The pre-existing epithelial cells of the cutis, as well as those of the sebaceous glands, become hypertrophic, and grow in the typical way into the under lying and surrounding tissues, in the shape of cylinders. Frequently the rapid increase in number of the epithelial cells causes the formation of pearl nodules. The periphery of the growth shows the usual zone of infiltration and inflammation.

2. *Adenoma* and *adeno-carcinoma,* especially of the Meibomian glands, but also of other glands in the tissues of the lids, have been found in a number of instances. When seen at the proper time it has been found that what originally was an adenoma had developed, later on, a carcinomatous character.

3. *Sarcomata* of the eyelids, at least those of primary nature, have been observed in small numbers (about fifty in literature). The eyelids are more frequently invaded by sarcomatous growths from the orbit and the surrounding tissues.

In the cases of primary sarcoma of the lid which have been observed, the patients were nearly all children. The tumors grew rapidly and soon infiltrated the whole tissue of the lid. The neoplasms were mostly of the round-cell type; in some instances, however, the growth belonged to the melanotic variety, and in still others it was composed of spindle cells, of cells of a myxomatous type, or of cells arranged in alveoli.

Of course, the danger to life due to sarcomatous growths makes their removal as urgent when they originate in the eyelid as when they develop in any other region of the body.

II. TUMORS OF THE CONJUNCTIVA.—A. *Benign Tumors of the Conjunctiva.*—1. *Lymphangiectasia* of the conjunctiva appears usually as a conglomeration of small, roundish elevations, filled with a watery fluid, and often strung together like beads. These little tumors give rise only very rarely to an inflammatory condition of the surrounding conjunctiva, and, as a rule, cause the patient no annoyance to speak of. When punctured they collapse, but are generally soon refilled. Their usual seat is the bulbar conjunctiva.

From the appearances presented under the microscope these tumors consist, undoubtedly, of distended lymph vessels. The little tumor is composed of a system of canals and cavities, which are in no way connected with the blood vessels. The latter show the more plainly, as they are usually hyperæmic. The cavities and canals just spoken of are separated from each other by trabeculæ of dense connective tissue, but they intercommunicate. The surrounding conjunctival tissue appears condensed and pressed aside. This system of canals contains a perfectly translucent serous fluid in which are suspended a number of lymphatic cells. The walls show, now and then, some traces of an endothelial coat (see Fig. 2060). The writer has had occasion to report a case of acute formation of hemorrhagic lymphangiectasia in an idiotic girl.

2. *Serous cysts* of the conjunctiva may undoutedly result from what was originally simply a lymphangiectasia; the septa existing between the canals and cavities of such a tumor having gradually yielded to the pressure, and all the cavities having thus become united into one. But serous cysts have also been found in the conjunctiva at birth, and they may develop without being preceded by a typical lymphangiectasia, especially after injuries, or they may be due to the cystic degeneration of small glandular lobules situated in the fornix.

They appear as round or oblong or oval swellings in the conjunctiva, and, owing to the nature of their contents, they usually present a somewhat yellow tinge. They are not, as a rule, movable under the conjunctiva, but they may become large enough to annoy the patient, and must then be removed.

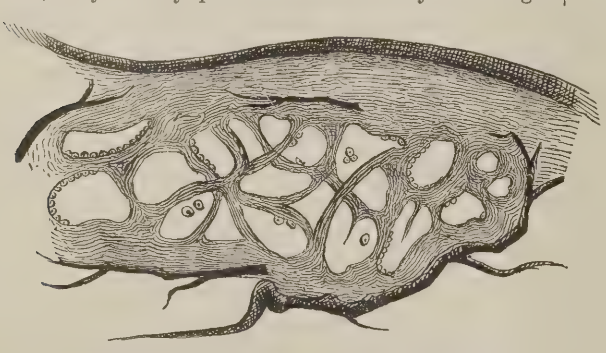

FIG. 2060.—Lymphangiectasia of the Bulbar Conjunctiva.

They have a well-defined cyst wall, consisting of connective tissue, and are usually lined with one or two layers of endothelial cells.

3. *Teleangiectatic* tumors are also occasionally found in the conjunctiva of the lids and eyeball, and usually there is then, at the same time, a teleangiectatic tumor in the lid. The seat of these tumors seems to be mostly in the region of the lachrymal caruncle.

Their histological structure is the same as that of other teleangiectatic tumors.

4. *Granulomata*, commonly called polyps, of the conjunctiva are comparatively frequent. They are red, softish nodules which project into the conjunctival sac; their mode of attachment to the conjunctiva being either by a broad base or by a slender peduncle. They are found chiefly near the inner canthus. They are due either to injuries or to chronic inflammatory affections of the conjunctiva, and may attain a considerable size, especially on phthisical eyeballs. Now and then they make their appearance at the site of a tenotomy for strabismus.

Their structure is that of all granulomata. They consist mainly of newly formed round cells and small spindle cells, here and there intersected by connective-tissue trabeculæ. This tissue is often full of blood-vessels, and usually contains a number of cavities filled with serous fluid. In rare cases the tissue is found to be of a higher organization, the granuloma being changed into a fibroma.

5. What has been described as *lipoma* of the conjunctiva is a subconjunctival growth of fat tissue. In the few cases which have been described this kind of tumor was congenital, in some it increased in size in later life. The subconjunctival lipoma appears as a yellow, roundish, and soft swelling, usually consisting of several lobules. They seem to be generally situated between the external and the superior rectus muscles.

According to the descriptions given of their histological structure these tumors are very closely allied to the dermoid tumors; it even seems as if they were dermoid growths with an excess of subcutaneous fat tissue. In one or two cases bone and fibrous tissue have been found in connection with such a fatty growth.

6. *Papilloma* of the conjunctiva has been found in a number of instances. The tumor, when seen, usually encroached upon the cornea, thus simulating a pterygium. Its histological examination alone revealed the true character. In one case reported by the writer, almost symmetrical papillomata developed in both eyes and, growing over the cornea, rendered the patient blind.

7. *Dermoid* tumors of the conjunctiva are always congenital tumors. Their seat is at the corneo-scleral juncture, and very frequently they lie partly in the corneal and partly in the conjunctival tissue.

The tumor appears as a grayish or yellowish round elevation, about the size of a pea—sometimes, however, much larger. Where it ends in the corneal tissue it is usually surrounded by a zone of gray corneal tissue, not unlike an arcus senilis. Conjunctival blood-vessels may enter it. Its surface is usually smooth and shining, and it may be partially or totally covered with fine hair. Sometimes one or more of these hairs grow very long and protrude through the palpebral fissure. Such a tumor may remain stationary a whole lifetime and cause no greater annoyance than what may be due to the growth of the hair. In other cases some irritation causes the tumor and its surroundings to become inflamed, and then the tumor may begin to grow and invade the thus far healthy tissue of the cornea. In such a case, or from cosmetic reasons, the removal of a dermoid tumor may become necessary, and is, as will be seen from the histological conditions, easily accomplished.

The dermoid tumor, as its name indicates, consists essentially of the elements of the skin. It is covered by epithelium, the outer flattened cells of which are, however, not always horny, but often undergoing a retrogressive metamorphosis. This is probably due to the moisture in which the surface of the tumor is continuously bathed. There are also usually a number of mucous cells to be found in this layer. This epithelial coat is uneven, like the surface of the skin, and numerous offsets are sent into the depth surrounding the papillæ of the tumor. From almost all of these indentations one or two fine hairs spring forth, and here lie also the orifices of the acinous glands, which are usually found in these growths. The connective tissue under the epithelium is very dense and fibrous. It contains elastic fibrillæ, and, as a rule, but few cellular elements, unless the tumor be in an inflammatory condition. The basis of the tumor, which is only very loosely connected with the episcleral tissue, is made up of fat tissue. Where the tumor lies on the corneal tissue, the union is usually a very firm one. These tumors contain a moderate number of blood-vessels, but it seems that they are but scantily supplied with nerves.

8. *True osteomata* of the conjunctiva have been observed in a small number of cases. The formation of bony tissue seems not to have been congenital. There appeared, in one case, a small tumor on the eyeball near the outer canthus, and it was removed on account of the annoyance which it caused. In another case the tumor had attained the size of a bean. The histological examination revealed true bone tissue.

9. The writer, on one occasion, removed from the eye of an infant a tumor which must be styled a *chondro-adenoma* of the conjunctiva. This tumor sat on the bulbar conjunctiva with a broad base, was whitish in color, and presented a perfectly smooth surface. The parents had observed it at the time of the child's birth, and thought that it had been gradually growing since that time. Its size was about that of a split pea when the writer saw it. The histological examination revealed the fact that it consisted of a large cluster of glandular tubules, resembling somewhat in their arrangement those of the lachrymal gland, and a large, roundish piece of embryonic cartilage. These two kinds of tissue were separated from each other, and together they were surrounded by a dense connective tissue.

B. *Malignant Tumors of the Conjunctiva.*—1. *Sarcomata* of the conjunctiva are of rare occurrence. They are either unpigmented, or, what is more frequently the case, pigmented. These tumors take their origin almost invariably from the region where the conjunctiva bulbi joins the cornea, that is, from the episcleral tissue at the corneo-scleral juncture, in rare cases from the loose tissue of the fornix. Their development has, in a number of cases, been ascribed to an injury.

The sarcomatous tumors of this region usually form roundish, sometimes lobulated swellings, which soon encroach upon the corneal tissue. They are very vascular, and bleed easily. They are usually of a rusty brown color, or they may even be almost black, at least in parts. Their surface appears smooth and shining, which is due to the fact that the growth for a long period remains covered by the conjunctival and corneal epithelium. Sometimes new nodules appear at some other point of the corneo-scleral margin, occasionally at a point diametrically opposite the original tumor. In their further development these tumors may spread into the interior of the eye, and, from the dissemination of their elements, death may ultimately result.

Histologically, the sarcomata of the conjunctiva are usually of the small round-celled variety. The original nodule, when growing on to the cornea, spreads for a time between the corneal epithelium and Bowman's layer, in the way pannus tissue is known to spread. Later on, Bowman's layer is destroyed at the periphery, and the sarcomatous elements invade the corneal tissue proper (see Fig. 2061). Yet the resistance of Bowman's layer is so great that the tumor will now spread underneath this layer into the cornea. In rarer cases the elements of the sarcoma are spindle cells. The pigmentation of the cells varies considerably in one and the same tumor. The more superficial parts are, however, usually the least pigmented ones. There is but very little intercellular substance. The large quantity of blood-vessels which these tumors usually contain has already been mentioned. There are always signs of former hemorrhages, and usually evidences of recent ones are to be found. In the propagation of these tumors the blood-vessels seem to play an important rôle, as they are sometimes found to be filled with pigmented molecules and pigmented cells. The periphery of these tumors is formed by a well-pronounced zone of inflammation.

2. *Epitheliomata* of the conjunctiva are more often observed than any other kind of conjunctival tumors. Although they are seen more frequently in persons of an advanced age, they make their appearance also in young individuals. They are generally situated on the bulbar conjunctiva, and, like the sarcomatous tumors, they most frequently start from a point near the corneo-scleral juncture.

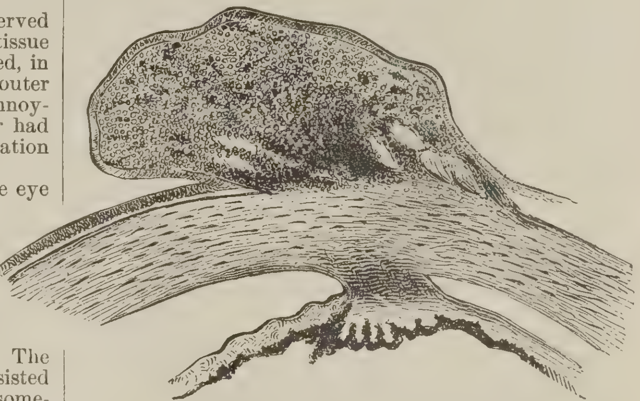

FIG. 2061.—Sarcoma of the Conjunctiva.

Their formation may begin with the development of a small phlyctenula-like nodule covered with hyperæmic blood-vessels; usually a number of larger and distended blood-vessels going to this nodule may be seen in the scleral conjunctiva. The growth may for a long period remain stationary, or it may keep on increasing gradually in size, or upon some special irritation it may start to develop rapidly, and be accompanied by inflammatory symptoms, and sometimes by considerable pain. The tumor usually spreads upon the cornea, which it may gradually penetrate, and thus find an entrance into the interior of the eyeball. The pain and suffering usually force the patient to submit to the removal of the eyeball before any further spreading of the elements of the tumor has taken place. In its early stages the new formation may be removed from the eyeball without much difficulty, as this has been stated of the sarcomatous new formations. Such epithelial growths of the conjunctiva have sometimes been found to be pigmented, and have then been described as *melanocancroids.*

The epitheliomata of the conjunctiva, like those found in other parts of the body, originate in a hyperplasia of the pre-existing epithelium. Thus we find in the beginning the epithelial layer considerably thickened, the serrated cells very numerous and well pronounced. In some cases we find a layer of horny cells of considerable thickness. This original tumor is usually surrounded by a tissue which is hyperæmic and infiltrated with round cells. When the tumor grows, epithelial-cell cylinders begin to dip into the underlying tissue and send off new branches. Gradually the new formation invades the cornea, this invasion being always preceded by the new formation of blood-vessels and by round-cell infiltration. Bowman's layer gives way, and the epithelial-cell cylinders spread into the corneal tissue proper. In the same way the epithelioma spreads into the sclerotic. Sometimes the surface of the tumor is ulcerated.

The epithelioma may spread into the interior of the eyeball. Thus it has been seen to invade the ciliary body and the choroid along an anterior ciliary artery, or the iris, after perforation of the cornea and anterior synechia had taken place. In some cases the conditions seemed to warrant the assumption that the external tumor had spread to the interior of the eyeball by metastasis.

The earlier the operation is resorted to, the easier is the removal of such tumors. This may be done successfully by means of either the knife or the galvano-cautery.

III. TUMORS OF THE CORNEA.—The cornea proper does not seem to be the seat of primary tumors. What has been described as such is to be found in section II. (Tumors of the Conjunctiva).

IV. TUMORS OF THE SCLEROTIC.—The sclerotic, like the cornea, does not seem to be a field for primary new formations. Those which have been described as such probably belong to the conjunctival (episcleral) tumors, and have, therefore, been treated under II.

V. TUMORS OF THE IRIS.—A. *Benign Tumors of the Iris.*—1. *Simple granulomata* of the iris have sometimes been observed, and have a number of times been mentioned in the older ophthalmic literature. They were described as small, round, yellowish, or grayish swellings, which made their appearance usually in the lower half of the iris. Gradually such a tumor would grow until it reached Descemet's membrane, and finally it would lead to perforation of the cornea. This generally was followed by shrinkage of the eyeball and the formation of scar tissue.

Histologically, these tumors are found to consist of round cells, and to contain numerous giant cells ("myeloplaxes"). Such a structure is so similar to that of tubercles that some recent authors have described the simple granuloma of the iris as tuberculosis of the iris. It is certainly strange that, since we have learned what tumors may grow in the tissue of the iris in consequence of syphilis and tuberculosis, no further case of simple granuloma of the iris seems to have been observed.

2. A special kind of tumor has been observed, in a few instances, to spring from the iris; it is generally mentioned among the cases of granuloma. This is a very vascular swelling, from which on slight provocation the anterior chamber would be filled with arterial blood. I should suppose that in such a case we would have to deal with a *teleangiectatic* tumor, rather than with a granuloma. The writer has had occasion to report the histological results of the examination of two cases of iris tumor which had been diagnosed as sarcomata, but which proved to be vascular tumors. The one had the character of a capillary, the other of a venous angioma. The cases reported as granulomata of the iris, accompanied by more or less periodical hemorrhages, have probably been of a similar character. A case described as a "papilloma of the subepithelial tissue of the iris" undoubtedly also belonged to this class of nævi.

3. *Traumatic granuloma* of the iris is occasionally met with,—in some cases after the corneal wound is perfectly healed, but in most cases after the iris has undergone a prolapse and is exposed to the air. In the former cases the granulation tissue was found to perforate the cornea, and cause perfect loss of sight in the same way as do malignant intra-ocular tumors. In the latter cases the tissue of the granuloma gradually becomes organized and forms scar tissue, and may thus bring about a spontaneous cure.

Such granulomata also consist of round cells and small spindle cells, and contain but little connective tissue and new-formed blood-vessels. Later on, the round cells gradually are changed into spindle cells, and finally we find a dense connective tissue containing but few cellular elements. The granulomata which start from a prolapsed portion of the iris are usually covered with epithelium.

4. *Melanoma* of the iris has occasionally been observed. It appears as a darker raised spot in the tissue of the iris, and it is, to say the least, as yet questionable whether what has been called melanoma was not in reality a melano-sarcoma. The authors usually state that a benign melanoma may at any time assume a malignant sarcomatous character.

Such a melanoma is said to consist of a circumscribed accumulation of "stroma cells of the iris, the larger part of which are pigmented, have many offsets, and anastomose with each other. They pass without a sharp boundary into the neighboring tissue, and the remainder of the iris is normal."

5. *Cysts* of the iris have been observed in a large number of cases. They are either serous cysts or cysts filled with epithelial material—epidermoid (atheromatous) cysts.

Cystic formations in the iris, as a rule, develop only after an injury. They begin as small, round, yellowish, or grayish tumors. The yellowish color is more characteristic of the epidermoid character, while the grayish or grayish-white color seems to be that of the serous cysts. Such cysts gradually grow until they reach Descemet's membrane, and then may become firmly adherent to it. Oblique illumination will usually show at once whether the cyst contains serum or some other material, for in the former case the tumor will be plainly translucent. In some cases the presence and the growth of such a cyst seem to cause but little discomfort; in others, however, severe inflammatory symptoms make their appearance, and sight may be destroyed.

The manner in which the formation of such cysts takes place is as yet not absolutely settled. But from recent experiments it seems that these cysts usually develop in small portions of epithelial tissue which have been forced into the iris by some previous injury; these parts enclosing organs which are apt to retain their contents and secretion. There can be no doubt, however, that in some cases serous cysts are formed, provided a fold of the iris becomes adherent to Descemet's membrane or to a wound canal in the cornea. The closure and subsequent expansion of iris crypts has also been mentioned as a possible cause for cystic formations.

The cyst walls have usually been found to consist of atrophied and attenuated iris tissue, lined with a layer of endothelial cells, and usually firmly adherent to the cornea. There is scarcely any pigment found in the cyst walls. The contents of the serous cyst are a perfectly transparent fluid, while the contents of the epidermoid cysts correspond with those of other atheromatous cysts and sometimes contain hair.

B. *Malignant Tumors of the Iris.*—*Sarcomata* of the iris have been met with in comparatively few cases. They have been mostly pigmented, but in a few cases they were unpigmented, or at least only slightly pigmented.

These tumors of the iris seem to have originated mostly in the parenchyma of this membrane, and near its sphincter edge. When allowed to grow, the tumor slowly spreads over the iris, and at the same time presses against the cornea, which it finally perforates. During its development it causes increase of intra-ocular pressure and inflammatory attacks, with subsequent destruction of sight. Later on, it leads to metastases. The rule is, undoubtedly, that these tumors grow on the anterior surface of the iris. The writer has in one instance seen a darkly pigmented sarcoma spring from the posterior surface of the iris near the pupillary margin, and, pressing the lens backward, spread into the interior of the eyeball. In its early stages sarcoma of the iris has been successfully removed by iridectomy; later on, the eyeball has to be sacrificed.

In the few cases which have been histologically examined the tumors were either pigmented round-cell sarcomata or sarcomata of the pigmented and unpigmented spindle-cell variety. They seem to take their origin from the parenchyma of the iris.

VI. TUMORS OF THE CILIARY BODY.—A. *Benign Tumors of the Ciliary Body.*—1. Up to the present time the writer has examined nine instances of *adenoma* of the ciliary body. These small tumors, which sprang from the pars ciliaris retinæ, were usually confined to one ciliary process, and seemed to cause no symptoms during life. Histologically, they consist of the cells of the pars ciliaris retinæ, arranged in double rows like glandular ducts, and these tubules form numerous convolutions. Between these tubules lies a coagulated amorphous substance. The tumors are surrounded by pigment epithelium. It is as yet not clear whether these adenomata are congenital or develop later in life.

2. *Myoma* of the ciliary body has only once been observed and described. In this case a brownish-red tumor was found to press part of the iris against the posterior

surface of the cornea and to protrude for some distance into the pupillary space. The tumor showed smooth elevations. There was increase of intraocular tension, and attacks of severe pain were complained of. The tumor grew slowly but continuously, and was considered to be a sarcoma. Finally, the patient consented to the enucleation of the eyeball. The tumor was found to have the size of a filbert, and to be firmly attached to the ciliary muscle. When divided it presented a cut surface of a roseate color, and it was only slightly pigmented in the peripheral parts. On microscopical examination it was found to consist almost exclusively of non-striated muscular fibres.

3. A *cyst* of the ciliary body has also been observed and described in a few instances, but these cases have not yet come to be examined microscopically. The cystoid formation followed an injury to the lid and eyeball. The cysts are described as oval bodies lying just behind the lens, springing from the ciliary region, and reaching with the larger end half-way across the eye into the vitreous. By oblique illumination the edge of such a cyst looks white, and can be clearly defined. Its surface is dotted, here and there, with pigment deposits. By direct examination with the ophthalmoscope the cyst walls are found to be transparent, and the details of the background of the eye may be dimly recognized through them unless they contain blood. These cysts have been observed to grow slowly, and to cause attacks of increased intra-ocular tension.

B. *Malignant Tumors of the Ciliary Body.*—Primary leuco-sarcoma and melano-sarcoma undoubtedly occur in the ciliary body, but are comparatively rarely seen, and yet more rarely examined microscopically. Moreover, these forms of tumors have nothing which would distinguish them from the sarcomatous growths of the choroid, and they are, therefore, best considered under that head (VII., B). Of late, in a number of instances, carcinomata of the ciliary body have been reported. They are described as having sprung from the pigment layer, more especially from the so-called glands of the ciliary body (Collins). This matter, however, needs further investigation.

VII. TUMORS OF THE CHOROID.—A. *Benign Tumors of the Choroid.*—1. *Granuloma* of the choroid is sometimes found in the course of histological examinations. Whether it has ever been clinically diagnosticated the writer does not know. In literature no mention is made of such a diagnosis.

In eyes in which the choroid has been injured (through the sclerotic), or in which round-cell accumulations have, after the manner of abscesses, perforated the lamina vitrea of the choroid, we find occasionally a small tumor consisting of granulation tissue, *i.e.*, of free nuclei, round cells and small spindle cells, and newly formed blood-vessels. These tumors may either lift the retina from the choroid and thus cause a circumscribed detachment of the former membrane, or they may pierce the retina also and protrude into the vitreous body. Later on, these granulation tumors are changed into connective tissue, and ultimately, after contraction has taken place, they form a simple scar.

There is one observation on record of the presence of small granulomata of the choroid in the eye of an individual who had long been suffering from "granular lids."

2. So far as I can learn, *cystoid* formations in the choroid have been seen only once, viz., by the writer, and then only in the course of the microscopical examination of an eye. They were found situated in the peripheral portions of this membrane, and formed a small number of round and oval cavities embedded in the parenchyma of the choroid. They had a membrana propria and were lined with endothelium. As regards their structure they were probably composed of dilated lymph vessels. The tissue of the choroid, which was displaced by these cystoid formations, was infiltrated with round cells and hyperæmic.

B. *Malignant Tumors of the Choroid.*—The only form of primary malignant tumor found in the choroid (and ciliary body) is that of the sarcoma in some one of its numerous varieties.

Since sarcoma of the choroid (and ciliary body) is undoubtedly the kind of intra-ocular tumor most frequently met with, we will give it a more extensive consideration, the more so as its clinical development is typical for that of all malignant intra-ocular tumors. It happens but comparatively seldom that we have occasion to see and diagnosticate a choroidal sarcoma, and afterward to verify our diagnosis by a microscopical examination at the period which is usually described as the first one in its development. At this stage the patient usually complains only of a diminution of sight. If the tumor springs from the ciliary region it can usually be recognized by the protrusion of the iris, and be seen under oblique light. The diagnosis is more difficult when the tumor is situated more centrally, or, as is frequently the case, near the optic-nerve entrance. The difficulty may be considerably increased if the retina at the site of the choroidal tumor has become detached. This seems, however, to be less frequently the case than was formerly stated by the authors. At this stage the ophthalmoscope may reveal one larger-sized, roundish elevation in some part of the background of the eye, or a flat elevation with a smooth or undulating surface covered by the retina, whose blood-vessels appear accordingly distorted in their course. The pigment of the sarcoma may perhaps be seen through the retina; even in cases in which the retina at the site of the tumor is detached it may be possible to recognize the latter through the retina with the aid of strong illumination and a high magnifying power. In most cases, however, it will be necessary to make repeated examinations of the fundus throughout a considerable period of time, in order to be able to determine whether there is any change in the picture and whether the supposed tumor increases in size. If an apparent detachment of the retina lying in the upper half of the eyeball, or to one side, remains confined to its original seat, and if the lower half of the retina does not become involved, the condition should be considered very suspicious of the presence of a choroidal sarcoma.

The growth of a choroidal sarcoma may vary considerably as to rapidity. While some reach the second period in, say, one year, others may take a number of years to reach the same stage.

The second period in the development of a choroidal sarcoma is characterized usually by an increase of the intra-ocular tension to a varying degree (glaucomatous stage), combined with inflammatory attacks and often severe pain. In some cases glaucomatous symptoms are wanting. In this period the tumor fills the vitreous chamber more and more, and pushes the retina, the condensed vitreous body, the usually cataractous crystalline lens, and the iris toward the cornea. Or it spreads through the whole uveal tract, forming, so to speak, a sarcomatous shell which encloses the retina, the condensed vitreous body, and the cataractous crystalline lens. In this period the eye usually shows, externally, the signs of a chronic inflammation.

The third period in the development of a choroidal sarcoma is usually called that of perforation and the spreading of the tumor outside of the eyeball. Thus the elements of the tumor usually grow through the sclerotic, along, or even by way of, a blood-vessel (venæ vorticosæ, anterior ciliary arteries, etc.), or through the channel of a ciliary nerve, or, what is quite often the case, when the tumor originates near the optic nerve, by way of this nerve or its sheaths, or by way of the intravaginal space. In other cases, the tumor will cause a staphyloma-like distention of the anterior parts of the sclerotic or of the cornea, and cause a rupture there. In this case the lens is usually expelled from the eye, and the tumor, no longer restrained in its growth by a resistant capsule, grows rapidly outward until the lids can no longer be closed over it.

At the same time dissemination of the elements of the tumor has usually taken place. Such elements taken up into blood-vessels are carried away by the current of the blood, and, wherever they are deposited, new (metastatic) tumors are formed, which ultimately cause the death of the patient. The organs which are usually attacked by such metastatic tumors are chiefly the liver, the lungs, pleura, intestines, kidneys, spleen, brain, etc.

In very rare cases sarcoma has been found to attack both eyes of the patient.

The development of sarcoma of the choroid is usually observed at an advanced age, yet it has also been found in very young individuals. It seems to be somewhat more frequent in males than in females. In a considerable number of cases its development may rightly be attributed to an injury.

Histologically, we find the choroidal sarcoma to be more frequently pigmented than unpigmented. The pigmentation varies considerably, however, even in one and the same tumor. The elements of the tumor are either round cells or spindle cells. The spindle cells seem to be prevalent in the unpigmented sarcomata. The round cells of the pigmented sarcomata (melano-sarcomata) are usually very large. The round-cell sarcomata are mostly very vascular. The spindle-cell sarcomata have generally but few blood-vessels, and in certain respects they present rather the characteristics of a fibroma. They also seem to grow more slowly than the round-cell sarcomata.

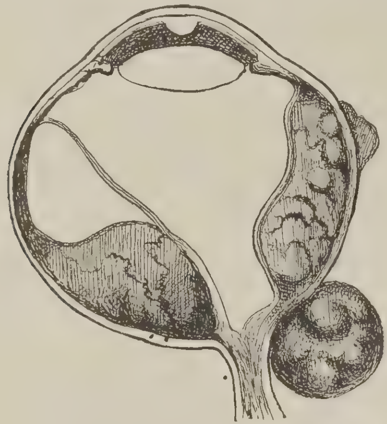

FIG. 2062.—Sarcoma of the Choroid.

The sarcomata of the choroid may take their origin from the different layers of the choroidal parenchyma. The statement has been made, and its correctness has been denied, that the unpigmented spindle-cell sarcomata spring usually from the outer layers of the choroid. The writer is satisfied that this is the correct view, and that the pigmented sarcomata, especially the darkly pigmented ones, spring as a rule from the inner layers of the choroid. They get their dark pigment from the broken-up cells of the pigment epithelium, and from hemorrhages. Sarcomata starting from the outer layers of the choroid may remain perfectly unpigmented, and grow to quite a size, until by the final perforation of the lamina vitrea of the choroid, and the subsequent breaking up of the pigment epithelium, a large quantity of pigment molecules is set free, and then only does the tumor become to some extent pigmented. Before this happens the pigment epithelium is usually found in a state of proliferation.

Occasionally there may be more than one primary sarcoma nodule in the choroid of one eye. From the primary nodule the sarcoma spreads in the choroid in the following manner:

When the elements of the original tumor have perforated the lamina vitrea of the choroid, detachment of the retina may take place, or the retina may remain in contact with the inner surface of the tumor and become firmly adherent to it. The choroid surrounding the tumor, which at first may appear normal, or hyperæmic and slightly infiltrated, is gradually invaded by the elements of the tumor. This invasion takes place at first in the outer (venous) layers. In these cases the growth of the tumor is a more diffuse one. In other cases metastatic nodules are formed in other regions of the choroid, at some distance from the primary nodule. Gradually the elements of the tumor reach the lamina suprachoroidea, and the tumor soon adheres to the sclerotic. This union is sooner or later followed by the perforation of the sclerotic and the growth of secondary nodules on the outer surface of the eyeball. As stated before, this perforation of the sclerotic takes place along a pre-existing canal (nerve or blood-vessel) in the sclerotic. In rarer cases the cornea is perforated by ulceration, and thus the tumor spreads outside the eyeball. On the other hand, the tumor may spread backward by way of the optic nerve. This happens in one of the following ways: the elements of the tumor may invade the substance of the nerve itself, or they may enter into the porus opticus along the central blood-vessels, or they may invade the intravaginal spaces of the optic-nerve sheath. The glaucomatous symptoms, which are observed in most cases of choroidal sarcoma, are due to the pressure exerted by the growth.

The sarcoma of the choroid is sometimes found to contain deposits of amorphous lime.

In rare cases osseous tissue is found to have been developed within the sarcoma (osteo-sarcoma).

Chondromatous tissue is found somewhat more frequently (chondro-sarcoma). It usually appears in the shape of round or oval islets, which are generally surrounded by a tough connective-tissue capsule, and lie near or around a larger blood-vessel.

In a few of the cases observed the sarcoma was a cystic sarcoma, and in another small number it was an alveolar sarcoma.

The spindle-cell sarcomata are, as a rule, hard and tough, while the round-cell sarcomata are softer, sometimes even semifluid.

In a few cases metastatic carcinoma has been seen in the choroid of women, the primary growth having its seat usually in the mamma. In a man the seat of the primary tumor was in the lungs and pleura. In one case a metastatic sarcoma was found in the choroid.

From the foregoing it is evident that, as soon as the diagnosis of choroidal sarcoma is made, the eye should be removed, as it is impossible to state when the tumor will spread outside the capsule of the eyeball, although this usually takes place only at a late period.

VIII. TUMORS OF THE RETINA.—A. *Benign Tumors of the Retina.*—*Teleangiectatic tumors* and small *fibromatous tumors* have been occasionally found in eyes examined anatomically, but they do not seem to have ever been observed during life, nor are they of any importance.

B. *Malignant Tumors of the Retina.*—The only malignant tumor observed to take its origin from the retinal tissue is the *glioma* of the retina.

Glioma of the retina (fungus hæmatodes) is essentially a disease of childhood; the oldest patient in whom it was undoubtedly observed was but twelve years old. It is probably, in most cases, a congenital affection.

As with the sarcoma of the choroid, we may divide the clinical history of the development of a glioma into three periods.

In the first period the growth causes but slight outward symptoms, and its existence at this period is but seldom discovered. The first symptoms, on account of which the parents bring the child for examination, are usually diminution or total loss of sight and the observation of a light yellowish or yellowish-red reflex from the pupil (amaurotic cat's eye). In this stage the pupil is also generally found to be dilated, probably from paralysis of the nerves of the iris.

The reflex from the background of the eye may at first be visible only in certain parts, and then the ophthalmoscope may reveal only a partially swollen retina, and the optic papilla may as yet be visible. Gradually the background of the eyeball is shifted more and more forward in the vitreous chamber, and it may now be possible to see different round nodules by the aid of oblique illumination. On the anterior surface of this yellow nodular mass a number of blood-vessels may be visible. Usually some whitish spots are seen, which correspond to parts which have undergone fatty degeneration, or to deposits of lime. Finally, the whole of the vitreous chamber is filled, and the tumor reaches the crystalline lens and presses it forward. This is usually soon followed by the formation of cataract.

Before this stage is reached, as a rule, the second period has begun, which is characterized by an increased intra-ocular tension, pain, and inflammatory symptoms. The eyeball is now frequently ectatic in the equatorial region; there is iritis, and soon the cornea ulcerates and is perforated. The blood-vessels of the conjunctiva and episcleral tissue are hyperæmic and tortuous. These symptoms are often combined with cerebral ones; there may also be fever and vomiting. The ulceration and perforation of the cornea, in rare cases, may be followed by the formation of scar tissue and shrinkage of the eyeball. Such cases have been described as cases of spontaneous healing of glioma; but even after a considerable period of latency the tumor makes its appearance again, and thus valuable time may have been lost.

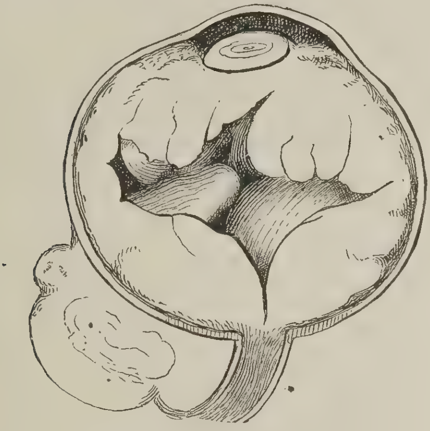

FIG. 2063.—Glioma of the Retina.

The third period is that of perforation. The glioma grows outward usually after the perforation of the cornea,—more rarely after perforation of the sclerotic. If it grows out through the cornea it increases very rapidly in size. The soft, easily bleeding, often partially necrosed tumor soon protrudes between the eyelids, and may in a short time attain an enormous size.

When the tumor has spread through the sclerotic, before the cornea has been perforated, the episcleral tumor or tumors may cause a considerable degree of exophthalmus. The tumor may furthermore invade the optic nerve and thus grow backward toward the chiasma.

Usually during this period secondary tumors are formed in the lymphatic glands of the face, in the parotid or submaxillary glands, in the bones of the skull, in the brain, in the liver, and in other organs.

Death follows from exhaustion.

In a large proportion of the cases (eighteen per cent.) glioma of the retina attacks both eyes. The affection of the second eye seems, however, not to be due to an infection from the one first attacked. Frequently several children of one family suffer from this new formation. It seems that it is more frequently found in males than in females.

The writer has reported one case in which glioma of one eye gave rise to sympathetic disease in the fellow eye.

In a few cases purulent choroiditis, with purulent hyalitis (pseudo-glioma), has been confounded with true glioma. In such cases, however, the intra-ocular tension is, as a rule, reduced, and pain seems to be wanting. Moreover, the eyeball appears rather shrunken than distended, as it does in a case of true glioma.

The opinion formerly held by the writer, in common with numerous authors, that histologically considered the glioma (or glio-sarcoma) of the retina must be counted among the small round-cell (medullary) sarcomata seems no longer tenable, since the characteristic "spider cells" of the glia have by Golgi's and Ramon y Cajal's process been demonstrated in glioma tissue. Besides these characteristic glia cells the elements of the tumor are round cells, smaller or larger than white blood cells, or identical with them. Sometimes these cells have small offsets. Between them we find free nuclei and some spindle cells. There is a very small quantity of intracellular substance. The tumors are usually very vascular, and their blood-vessels are very wide. The cells seem to be very prone to degenerate. Rosettes, formed by the rods and cones, have been given of late an undue importance in the histology of glioma. In the opinion of the writer they are purely accidental formations. Tumors in which they were found have of late been called neuro-epitheliomata, these cells belonging to the so-called neuro-epithelium of the retina.

The tumor usually takes its origin from the outer retinal layers, especially the granular layers; in rarer cases its primary seat is in the inner layers, especially the nerve-fibre layer. In some cases it appears as if the whole thickness of the retina had been primarily affected, and, in fact, the tumor may take its origin from the connective tissue of all the layers of the retina.

As already stated, the glioma cells are apt to undergo fatty degeneration, and deposits of lime are often found in these tumors.

When the tumor starts from the outer layers (*glioma exophytum*), the retina in its neighborhood soon becomes detached and is pressed toward the axis of the eyeball. In these cases the inner layers of the retina may remain intact for a long time. On the other hand, when the tumor has started from the inner layers (*glioma endophytum*), the rods and cones may be preserved for a long period. The tumor gradually spreads all over the retina, and enters the choroid either simply by continuous growth or by infection (metastasis). During the growth of the tumor, parenchymatous hemorrhages frequently take place within it. Later on, the tumor may spread into the ciliary body and the iris, and we may thus find an eyeball filled perfectly by glioma, and but few traces of its former structures left.

At a comparatively early period, usually, the elements of the tumor invade the substance of the optic nerve.

The perforation of the sclerotic, and the formation of secondary tumors outside of it, generally take place along a preformed channel (nerve or blood-vessels), as we have seen it take place in the development of the sarcoma of the choroid.

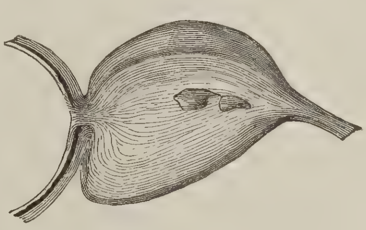

FIG. 2064.—Myxo-sarcoma of the Optic Nerve.

Glioma is known to be pre-eminently a malignant growth; therefore the removal of the eyeball, or even of the whole orbital contents, is necessary at the earliest possible period. In this way the life of the patient has been saved in a number of cases.

IX. TUMORS OF THE OPTIC NERVE (ORBITAL PORTION).—The tumors of the orbital portion of the optic nerve have a number of symptoms in common, whatever the nature of the growth may be, the chief ones of which are loss of sight and exophthalmus. The latter is often the first symptom to be observed. This exophthalmus is, as a rule, in a straight forward direction, yet there may also be a deviation in another direction, if the tumor should develop more rapidly to one side. The eyeball can usually be moved, but its movements are restricted in all directions; later on, they may be totally abolished. If the tumor is large enough to be palpated, it is found to move with the movements of the eyeball, and to be nowhere attached to the orbital walls. When it is small it cannot be felt. In a number of cases the development of the tumor is attended with severe pain; in most cases, however, this symptom is wanting. In all cases sight gradually fails. In the early stages the ophthalmoscope reveals optic neuritis; later on, we find white atrophy of the optic nerve. The rapidity with which sight is abolished varies considerably in the different cases, and this is, of course, due to the manner in which, in the given case, the nerve itself is constricted or invaded by the elements of the neoplasm. Thus, when the tumor originates in the outer sheath, sight will be preserved longer than when the new formation has its origin in the perineurium or the substance of the nerve itself. As the tumor grows and pushes the eyeball out of the orbital cavity, the cornea becomes less and less protected by the lids, and finally this membrane ulcerates and is perforated.

It seems that in all the known cases, except one, the tumor with the eyeball, or the tumor alone, has been removed and a perfect cure has been obtained. From this it would appear that tumors of the optic nerve, *quoad vitam*, are not to be considered malignant.

As regards the nature of the tumors of the orbital portion of the optic nerve they seem to be chiefly myxomatous (myxo-sarcomatous) or gliomatous; in some cases the tumors had to be interpreted as endotheliomatous (psammoma), and a few cases, described as cancers of the optic nerve, most probably belong to this latter class. In one case the tumor was found to be a true neuroma. In a few cases the tumor has been described as being formed by a hypertrophy of the pia mater trabeculæ which hold the nerve-fibre strands in position.

Being enclosed within the space which is limited by the muscles of the eyeball, and the posterior aspect of the sclerotic, all of these tumors are more or less spindle-shaped (see Fig. 2064).

1. *Myxoma* or *myxo-sarcoma* of the optic nerve consists of spindle-shaped and stellated cells, with long offsets. These cells are usually packed more densely in the central parts of the tumor than in the peripheral ones. They are separated from each other by a hyaline intercellular substance. The cells often appear concentrically arranged, and thus form nests which resemble the pearl nodules of epitheliomatous neoplasms. These tumors are, furthermore, well provided with blood-vessels. The mucoid substance is often found to be accumulated in cysts of varying dimensions. Closely adherent to the new formation are the sheaths of the optic nerve, which form a capsule around it. Sometimes some traces of the optic nerve may yet be found in the centre of the tumor.

2. *Glioma* (glio-sarcoma) of the optic nerve shows the same elements as we find in cases of glioma of the retina, viz., round cells varying in size, cells with offsets, and spindle cells.

3. *Endothelioma* (psammoma) of the optic nerve consists of connective tissue, in the alveoli of which cells lie embedded in more or less concentric layers. These cells are large, flat, membrane-like bodies, somewhat thicker at the spot where the nucleus is situated. Their contours are not sharply defined, and some of them have long offsets. Giant cells are not wanting. These cells, the nature of which is that of endothelial cells, are often grouped concentrically around a round or oval shining body (arenoid body), from which these tumors have also received the name of psammoma.

4. In the only case of true *neuroma* of the optic nerve thus far described in literature, the whole egg-shaped tumor consisted of double-contoured as well as of non-medullated nerve fibres.

X. Tumors of the Orbit.—The chief symptom of orbital tumors, and the one which they all have in common, is exophthalmus—protrusion of the eyeball. This protrusion may, of course, take place in any direction, and we can only state, as a general rule, that it is in a direction opposite to the site of the tumor or to its greatest development. Usually the movements of the eye in the direction toward the tumor are impaired or abolished. While some orbital tumors cause a great deal of pain, others do not seem to cause any. According to the seat and size of the tumor, sight will be more or less impaired or totally destroyed, and we find accordingly, with the ophthalmoscope, simple anæmia or optic neuritis or atrophy of the optic nerve either partial or total.

Orbital tumors do not seem to be apt to invade the optic nerve, or the eyeball, but they generally grow around it. On the other hand, tumors from the cavities adjacent to the orbit may and do invade this cavity. Such tumors have been found to come from the ethmoid cells, the naso-pharynx, the frontal sinus, Highmore's antrum, and the sphenoid cavity, as well as from the cranial cavity. These growths are sarcomatous, endotheliomatous, or osseous in character.

As a rule, one may locate the tumor by palpation, and it is possible to distinguish one of orbital origin from a tumor of the optic nerve by its situation outside of the cone formed by the external muscles of the eyeball, and by its being in many cases adherent to the walls of the orbit. As the tumor (and consequently the exophthalmus) grows, the upper lid is dragged along, and it often continues to protect perfectly the cornea even when the eyeball protrudes to an enormous degree. The lid is then in the condition which we call paralytic ptosis.

When the lid can no longer protect the cornea, ulcerations take place, and perforation of the cornea may be the result. According to the nature of the tumor it may, of course, invade the brain, and cause metastatic tumors to be formed in other organs, and thus bring about the death of the individual. When the orbital tumor cannot be easily removed without detriment to the eyeball, Kroenlein's osteoplastic method should be employed.

A. *Benign Tumors of the Orbit.*—1. *Cysts* of the orbit have been designated, according to their contents, as hygroma, meliceris, oil and fat cysts, and atheromatous, hæmatomatous, or steatomatous cysts. They all are probably congenital and *dermoid* in character, and owe their existence to faulty development during fœtal life. This is the more probable, since some of the cysts have been found to contain a tooth, or hair, or other epithelial formations. In many of the cases the cysts were distinctly known to have been congenital, and in another number they were observed in small children. There is usually but one cyst, although in some cases several have been found. Their size varies considerably. They lie mostly outside of the cone formed by the external muscles of the eyeball, and seem to be situated more frequently in the temporal parts of the orbit than in any other region. They may extend far back into the orbital cavity.

These tumors increase but slowly in size, unless stimulated to a more rapid development by an injury, and they do not give the patient much discomfort until they are large enough to cause exophthalmus and displacement of the eyeball, which is, of course, in the direction opposite to the growth. They now may generally be seen as bluish swellings in the lid (generally the upper one), and may even be directly demonstrated by eversion of the lids. It may be possible to detect fluctuation in the tumors, yet this can hardly be done with any degree of satisfaction, and it is therefore better to make sure of a correct diagnosis by the use of an aspirator.

Cysts of the orbit seem to be equally frequent in both sexes, and have mostly been observed in young people.

2. *Angiomata* of the orbit are either cavernous or teleangiectatic (erectile tumors).

a. The cavernous angioma of the orbit, which can attain a very considerable size, is either congenital or develops in later years. It is usually situated in or starts from the fat tissue within the cone formed by the external muscles of the eyeball. The tumor is often surrounded by a tough capsule of connective tissue. It may, as a rule, be seen as a bluish swelling under the skin of the lid, and from this similarity with orbital cysts mistakes in diagnosis have occasionally occurred. A characteristic symptom of the angioma is, however, that everything tending to hinder the reflux of the venous blood will cause a swelling and protrusion of the angioma; furthermore, the tumor may be compressed and emptied. The growth of the tumor is slow, and it is not apt to cause any pain. In rare cases a spontaneous cure has been observed. The removal of the tumor is practicable, and the more readily so the earlier it is undertaken.

β. The teleangiectatic tumors of the orbit are usually found to be accompanied by similar tumors in the lids and neighboring tissues, and they also form soft, compressible swellings. This kind of angioma seems to grow more quickly than the cavernous angioma. It is desirable that the growth should be removed at an early period.

3. *Lipoma* of the orbit has been described a few times. Yet it seems that in these cases the lipoma originally involved the eyelid.

4. *Enchondromatous tumors* of the orbit occur but rarely, if at all. The descriptions of such tumors thus far laid down in literature are, to say the least, doubtful.

5. *Osteoma* of the orbit has been often observed. It takes its origin from the diploë of the walls of the orbit. It is generally an ivory exostosis, sometimes partially spongy or cartilaginous. Its seat of predilection seems to be the upper inner wall of the orbit. In some cases osteoma has been found to develop symmetrically in both orbits of the same individual. These osteomata are usually round tumors, hard, and with a smooth or nodulated surface, and are mostly attached to the underlying bone by a broad basis. Their growth into the orbits may take place simultaneously with the growth of similar tumors into the neighboring cavities, or they may originally have started in one of the neighboring cavities and from there have grown into the orbital cavity. Their growth is most likely due to some faulty development during fœtal life.

Such tumors grow very slowly; in some cases their development is accompanied by pain. They may cause exophthalmus with all its sequelæ. When superficial, they are easily recognized by their seat, and by their consistency and immobility. It has, however, happened that retention cysts pointing into the orbit from a neighboring cavity, have been mistaken for osteomata. The tumors under consideration may have to be removed on account of their danger to the eyeball and its functions. Their removal is sometimes comparatively easy, yet it may be attended with danger from subsequent meningitis.

Histologically these tumors are found to consist of bone tissue. In most cases this tissue was found to be extremely compact and to be almost bare of Haversian canals (ivory exostoses). In other cases they contained varying quantities of marrow.

6. *Lymphoma* and *lymphadenoma* of the orbit have been described, but they took their origin probably not from the orbital tissue proper. Lymphangioma has also been found in the orbit.

7. Benign tumors consisting of striated muscular fibres and nerve fibres have in a few instances been removed from the orbit. The writer has seen a *rhabdo-myoma* and a *myo-neuroma* of the orbit.

B. *Malignant Tumors of the Orbit.*—1. *Cancer* of the orbit has been described as epithelioma, cancroid, adenoma, and adeno-carcinoma. It seems, however, that such new formations do not take their origin from the orbital tissue, but, having originated in the tissue of the eyelids, the episcleral tissue, or the lachrymal gland, have gradually invaded the tissues of the orbit. It is, therefore, not probable that a primary cancer of the orbital tissue has ever been observed.

2. *Sarcoma* of the orbit has frequently been observed and described. Its clinical diagnosis is extremely difficult, since we have but scanty means on hand wherewith to distinguish the nature of a tumor which has its seat in the deeper parts of the orbit. When the nature of the tumor is recognized, its removal with or without the simultaneous removal of the eyeball is, of course, imperative. Sarcomata have their origin usually in the orbital tissue. In a few cases the tumor had started in the brain and secondarily invaded the orbit. There are cases in which such an invasion takes place more or less symmetrically in both orbits.

A variety of forms of sarcoma have been described.

a. *Cylindroma*, a form of sarcoma characterized by a system of wide, anastomosing canals with larger cyst-like cavities filled with fluid, or gelatinous or fibrinous contents, has but very rarely been found in the orbital tissue.

β. *Myxo-sarcoma* of the orbit has been observed in about a dozen cases. These tumors were seen more frequently in children and young individuals than in older ones. In some their growth was a very rapid one, and in some it was accompanied by severe pain. The tumors consisted of long spindle and stellate cells, with a mucoid intercellular substance.

γ. *Round-cell* and *spindle-cell* sarcomata are the most frequent ones among the orbital sarcomata. In some cases they are melanotic.

δ. *Osteo-sarcoma* of the orbit always springs from the bony walls of this cavity. It seems to spring most often from the inner upper part of the orbital wall. It is usually a small round-cell or spindle-cell sarcoma, with spicula of bone tissue embedded in it. These spicula of bone tissue may be very numerous, and make the tumor appear very hard to the touch.

ε. The writer has recently examined and reported the case of an orbital tumor, which was situated over the nasal wall of the orbit and which proved to be a *myo-fibro-sarcoma*. The elements of which it consisted were very numerous unstriped muscular fibres and bands of denser fibrous tissue; in some parts giant cells and spicula of bone were situated.

3. Another form of malignant growth found in the orbit is that known as *chloroma*. It consists of small round cells undergoing a peculiar fatty degeneration accompanied by a greenish-brown color. It springs from the periosteum. Probably it is also a sarcoma.

XI. TUMORS OF THE LACHRYMAL GLAND.—The tumors of the lachrymal gland may be diagnosticated by their situation in the outer upper part of the orbit, and by the consequent exophthalmus inward and downward (at least at the beginning of the development). These tumors generally grow but slowly. Gradually they cause a bulging of the upper eyelid, most marked near the outer canthus, and it is, as a rule, now possible to palpate the tumor, or even to see it protruding into the conjunctival sac, pushing the upper fornix downward. By palpation a tough, lobulated swelling is felt, which may be slightly movable; in most cases, however, it is immovable. When the tumor grows it often fills the posterior parts of the orbit, and thus it may cause the exophthalmus to change its direction, and when the tumor has filled the apex of the orbit altogether, and has grown around the optic nerve (which tumors of the lachrymal gland never seem to invade), the eye may stand straight forward, as if there were a tumor of the optic nerve. For this reason the movements of the eyeball, which at first are restricted only in an upward and outward direction, may become, later on, restricted in other directions too, and even finally be totally abolished. If the tumor grows still further, ulcerations of the cornea, etc., may take place. During the development of such a growth, the optic nerve is, of course, considerably pressed upon and stretched, and accordingly we find it anæmic, or swollen and inflamed (optic neuritis), or atrophied. From the state of nutrition in which the nerve is when the tumor is removed, it will depend how far sight may be recovered. This removal may frequently be accomplished without sacrificing the eyeball.

Tumors of the lachrymal gland are usually observed in individuals of an advanced age, and their origin is sometimes attributed to an injury. Sometimes the lachrymal glands of both orbits in one individual have been found to be similarly affected. The tumor may, by entering the cavity of the brain and the brain substance, cause the death of the patient.

Various forms of tumors of the lachrymal gland have been observed, but opinions differ very considerably with regard to what may be considered a tumor of the lachrymal gland and what not.

The writer has seen and examined the following forms of tumors, which unquestionably took their origin from the lachrymal gland.

1. *Adenoma* of the lachrymal gland shows the typical picture of an epithelial neoplasm. Epithelial-cell cylinders, which compose the bulk of the tumor, lie embedded in a small quantity of connective tissue. The cells of every one of these cell cylinders are arranged around a central canal, which in some cases is very considerably enlarged by a transparent fluid. The cell cylinders are made up of one layer of polyhedral, almost cuboid epithelial cells, and have a distinct membrana propria.

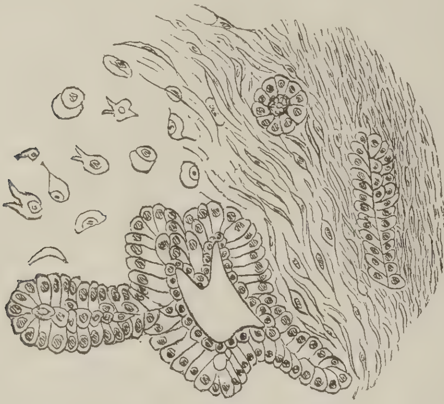

FIG. 2065.—Enchondroma Myxomatodes Carcinomatodes of the Lachrymal Gland.

The lachrymal gland has also, in a number of instances, been the seat of *adeno-carcinoma*, of *lymphoma*, and of *lymphadenoma*.

2. *Myxoma* and *myxo-sarcoma* of the lachrymal gland are characterized by the development of spindle cells with long offsets, and stellate cells embedded in a mucoid intercellular substance, and by the gradual disappearance of the glandular structure. This kind of tumor of the lachrymal gland is, however, but seldom observed alone. It is more frequently the case that the glandular tissue does not disappear, but, instead, an atypical growth of tissue takes place, at least in some parts of the tumor, and thus gives to it the character of an adeno-carcinoma. In some cases we find, moreover, besides these two kinds of new formations, a number of islets of hyaline cartilage tissue. Thus, instead of a simple myxoma or myxosarcoma of the lachrymal gland, we have then a myxoma carcinomatodes, or a myxoma carcinomatodes chondromatodes. In other cases the hyaline cartilage may be the prevailing tissue; in which case we would have to call the tumor an enchondroma myxomatodes carcinomatodes.

3. *Spindle-cell sarcoma* of the lachrymal gland has been described by a number of writers. In one of my own cases the tumor developed quite rapidly, and consisted of densely packed spindle cells in its older portions. The younger portions of the tumor showed round cells and small spindle cells. Not a trace of glandular tissue was found.

4. *In lympho-sarcoma* of the lachrymal gland the bulk of the tumor consists of densely packed lymphatic cells, with hardly any intercellular substance.

5. *Epithelioma* of the lachrymal gland is formed when an atypical growth of the epithelial elements of the glandular tissue takes place. We find, then, instead of the glandular apparatus, solid epithelial-cell cylinders and nests of epithelial cells. This form of growth seems, however, generally to be combined with the development of myxomatous tissue in the lachrymal gland. The cases described as epithelioma of the lachrymal gland should probably with more correctness be regarded as cases of adeno-carcinoma.

6. In the older ophthalmological literature, a number of cases of *cystic degeneration* of the lachrymal gland, or its ducts, have been described as *dakryops*. These cysts grew very slowly, and had to be removed on account of their impairing the motility of the eyeball. It is not known whether the whole of the lachrymal gland is likely to undergo such a change.

XII. TUMORS OF THE LACHRYMAL CARUNCLE.—The lachrymal caruncle is sometimes the seat of a new formation. Thus, congenital dermoid tumors have been observed in this region. Papillomata are not rare.

In advanced life the caruncle may become the seat of epitheliomatous new formations as well as of sarcoma. The latter kind of tumors are usually pigmented. The development of these tumors is almost always attributed to an injury.

XIII. TUMORS OF THE LACHRYMAL DRAINAGE APPARATUS.—In rare cases small *granulomata* (polyps) have been found in the lachrymal sac, and even in the lachrymal canaliculus. It is obvious that such little tumors may gain some clinical importance by the stoppage of the canals through which the tears ought to be carried off. Their formation is due to chronic inflammatory conditions of the mucous membrane of these channels.

Adolf Alt.

EYELIDS, AFFECTIONS OF THE.—The eyelids present two surfaces, both of which are subject to disease. The posterior, or under surface, *i.e.*, the surface which is in contact with the eye, is covered with conjunctiva, and affections of this surface are described under this head. (Cf. *Conjunctiva, Diseases of.*) In describing the affections of the eyelids we have to consider the anterior or upper surface, and the structure between the two surfaces.

The upper surface of the eyelid is covered with integument which is continuous with the integument of the forehead and face. It differs from the integument of the forehead and face in being thinner. Under the skin of the eyelids we find the subcutaneous areolar tissue, which frequently becomes infiltrated with effusions, and distended with air in injuries to the nose and air sinuses. The next tissue is the orbicularis muscle, the function of which is to close the eyelids. This is the muscle which is affected in paralysis of the facial nerve, producing inability to close the eyelids, or, as it is sometimes called, lagophthalmus. Beneath this muscle are the tarsal cartilages, upper and lower, the functions of which are to add to the protection of the eye, to preserve the contour of the lids, and, in the upper lid, to give attachment to the muscle which raises the lid—the levator palpebræ superioris.

The tarsal cartilages contain in their substance the Meibomian glands, whose sebaceous secretion lubricates the edges of the lids. The tarsal cartilages are thicker at the free margins of the lids, and gradually taper back to a thinner edge; they are about one inch in length. The upper cartilage is about one-third of an inch in breadth at its centre, and narrowing toward its outer and inner extremities has a somewhat semilunar shape. The cartilage of the lower lid is much smaller in width, having a more or less elliptical shape. The free margins of the upper and lower lids—*i.e.*, the edges where the anterior or cutaneous surface and the posterior or conjunctival surface meet—lie in contact with each other when the eye is closed, and contain the cilia, or eyelashes, together with the openings of the ducts of the Meibomian glands. The extremities of the margins of the upper and lower eyelids are joined together, and are called the outer canthus and the inner canthus.

These canthi, with the extremities of the cartilages, are attached to the frontal processes of the superior maxillas at the inner sides, and to the malar bones on the outer sides, by the canthal ligament. It is important to bear this in mind in operations on the outer canthi especially.

The inner canthi are shaped somewhat like horseshoes, and at the free extremities of the shoes are the openings of the lachrymal canals, the puncta lachrymalia. Under the tarsal cartilages is the palpebral portion of the conjunctiva.

The eyelids are subject to diseases affecting the integument generally, as well as to affections peculiar to themselves, because of the structures involved.

The departures from the normal which may affect the cutaneous surfaces of the eyelids, either separately or in common with the skin of the forehead and face, are, erysipelas, exanthemata, ecchymoses, herpes, œdema, emphysema, venereal sores, eczema, and acne.

Erysipelas and exanthematous diseases seldom, if ever, attack the eyelids except as they affect the cutaneous surface generally. Erysipelas is never confined to the integument of the eyelids alone, except that the attack may originate in this situation and spread to other parts. Its restriction to the eyelids, under these circumstances, would be only temporary, lasting, at most, not more than forty-eight hours. The writer has seen a patient attacked with what appeared at the onset to be a purulent conjunctivitis, with eyelids red, swollen, and œdematous, together with a moderately profuse purulent discharge from the conjunctiva, develop in less than thirty-six hours into a case of facial erysipelas, the eye symptoms subsiding as the disease spread over the face. There are none of the exanthemata in which the eruption manifests itself first about the eyelids, and when the eyelids are involved it is only as a part of the general cutaneous involvement. Eczema may manifest itself on the eyelids as the result of a general facial condition, or may be secondary to the inflammatory condition of the edges of the lids known as blepharitis; of this we will speak later.

Acne may also affect the eyelids as the result of a general cutaneous affection.

The treatment of these general inflammatory affections of the integument of the eyelids does not differ from the treatment of the same disease when located elsewhere in or on the cutaneous surface. It may be necessary to be cautious in the employment of lotions, embrocations, and ointments, containing irritating substances, because of the danger of injuring the delicate structure of the eye itself, but other than this the treatment of affections of the lids, such as we have mentioned, will not differ from the usual treatment employed when these affections are situated in other parts of the body.

Venereal sores which may affect the integument of the eyelids are chancres, chancroids, and venereal ulcers. One would be naturally suspicious of the nature of an ulcer or sore on the eyelid in a patient known to be suffering from syphilis, or in one who had chancroids or sores known to be of venereal origin, located elsewhere. Even when symptoms of venereal disease do not exist elsewhere, venereal sores may exist on the eyelids. When patients present ulcerations of the integument of the eyelids which do not yield promptly to treatment, and which the microscope does not demonstrate to be malignant, our suspicions should be aroused at once as to their possible venereal origin.

Chancres of the integument of the eyelids are not so common as chancres of the conjunctiva, and we do not wish to be understood as intimating that they are commonly met with in the latter situation. They are, however, occasionally encountered in the integument of the eyelids, and are not always easily distinguished, macroscopically, from malignant diseases, especially epitheliomata. The diagnosis may have to be made with the microscope.

The treatment of venereal sores and ulcers will depend on whether their origin is syphilitic; but whether syphilitic or not, their treatment will differ radically from the treatment of malignant growths or neoplasms.

Syphilitic and venereal sores and ulcers of the eyelids will require the local and constitutional treatment commonly given this class of affections without regard to their situation. Malignant growths, on the other hand, will generally require operative treatment.

Herpes affecting the eyelids, oftener the upper, is not uncommon. We commonly meet with a mild form of herpes—fever sores as they are called—but we also meet with a severe form, the two differing so as almost to warrant describing them as different affections. We have herpes in the mild form, occurring as the result of febrile disturbances in children, occasionally also in adults. It may follow exposure to high winds, sunburn, and irritations of the skin generally. The herpetic eruptions from these causes affect all parts of the integument of the face indiscriminately, often both sides at the same time, including the eyelids. There appears a slightly elevated red spot, more or less rounded in outline, varying in size from 3 to 20 mm. in diameter, or even larger. This red spot tingles and burns, and in twenty-four hours begins to be vesicular in character, composed of a number of small vesicles. The fluid in these vesicles, which in the beginning is watery, soon becomes flocculent, changing into pus. The vesicles coalesce and break down, forming a scab. If this scab is removed we find the surface beneath ulcerated. Whether removed or not, the sore heals in a week or ten days, leaving a reddened surface, which may persist for a week or two weeks longer. Attacks of herpetic eruption such as this are of frequent occurrence in neurotic people, the result of some slight nervous irritation, or of direct irritation of the terminal endings of the sensory nerves. The course is mild, the treatment palliative, and the prognosis good.

We have another form of herpes, as we have said, known as herpes zoster, which affects the supra-orbital branch of the fifth nerve, generally unilateral, and often very serious in its consequences. Herpes zoster is ushered in with violent pain over the distribution of the nerve, producing intense supra-orbital neuralgia, which may last a day, or even two days, before the eruption takes place, and at times persisting during and after the eruptive period. The skin of the upper eyelid becomes reddened and swollen, and the lid itself œdematous. There is more or less marked febrile action. The eruption appears to be the same as that described in the simpler form of herpes, except that the underlying ulcers are deeper and frequently leave scars. The condition takes its name from the parts affected, as herpes zoster frontalis, herpes zoster palpebralis, and herpes zoster ophthalmicus. When it affects the eye itself (herpes zoster ophthalmicus) very serious results, even destruction of the eyeball, may follow.

The writer has seen several cases of herpes zoster affecting the eyelids and forehead which have been diagnosed by attending physicians who were not familiar with the disease as erysipelas, all coming from malarial districts.

The treatment consists of cathartics, hot applications to the affected parts to relieve the pain, and even opiates may be necessary. During the beginning of the eruptive stage, the intense irritation may be allayed by applications of weak solutions of acetate of lead, lead and opium wash, or carbolic acid. After the vesicular stage has passed, an ointment of carbolic acid and vaseline will soften the scabs and prevent, possibly, the formation of deep scars. In the writer's experience the best results have followed the internal administration of quinine.

Œdema of the eyelids is a symptom of importance in affections of the eye itself, as denoting the intensity of the exciting cause, which is generally of an inflammatory nature. Œdema may occur in the eyelids also because of disease of organs remote from the eye, as in cardiac and renal disease, and in anæmia.

When due to local causes situated in the eye or adjacent structures, the amount of the œdema will generally be in proportion to the intensity of the disease which produces it, as well as to the location of the affection. For example, we frequently find in iritis, both primary and when due to cataract extractions, an œdema of the lids at the inner canthus. The same will be true of keratitis, scleritis, tenonitis, and inflammations of the eye and its appendages generally. Œdema of the eyelids from affections of the eye itself is never so extensive or marked as we sometimes find it as the result of purulent inflammations of the conjunctiva, dacryocystitis, panophthalmitis, frontal-sinus disease, and retrobulbar abscesses or tumors, in which affections it may become so marked as to threaten the destruction of the eye from pressure. Œdema of the eyelids may also be present as the result of stings of insects. There is ordinarily very little to be done for œdema of the eyelids. When due to renal disease it is more pronounced after rest in a recumbent position; when due to cardiac disease it is more or less constant, although more pronounced after physical exertion. There is no local treatment which will remove œdema when due to these two causes. If we find associated with the œdema—as we sometimes do—an irritation of the eye and the under surface of the eyelids, we can obtain a certain amount of relief from the use of biborate of soda and tannic acid, each ten grains to the ounce, or a solution of boric acid in camphor water.

When due to inflammatory conditions of the eye and surrounding parts there is nothing to be done for the œdema itself—beyond the application of a light bandage —except when the swelling of the lids is so great as to threaten the eye, when the pressure can be relieved by the operation known as external canthotomy, or division of the external canthus. Such extreme treatment is, of course, seldom necessary.

It this connection we may mention an affection of the eyelids which may be mistaken for œdema. This is emphysema, due to injury of the nose or of the sinuses which surround the eye. The onset is sudden, following a traumatism, and characterized by swelling of the eyelids, one or both, depending on the situation and extent of the injury. There may be redness of the integument of the lids,—which, in fact, is true in any swelling of the lids, even when not of an inflammatory nature; and palpation gives to the fingers a crackling sensation. This distention is apt to be more marked in the lids than in the surrounding parts, for the reason that the integument of the lids is so loosely connected with the underlying parts, and its areolar tissue has so little adipose tissue in its meshes that it becomes easily inflated when the walls of the sinuses, or other air cells which abound in this situation, are broken. No treatment is necessary for the emphysema itself, except in extreme cases, when a bandage may be applied. When the cause of the emphysema is removed the air disappears.

The pathological conditions grouped and described under the heading of skin diseases may affect the integument of the eyelids, acne and comedo being perhaps the least common, while milium, molluscum, and xanthelasma occur frequently; acne merits, at our hands, no description, differing in no way from the acne seen in other parts of the body. Comedones, or black-heads, can be removed, here as elsewhere, excepting that while in other parts they may be removed with the time-honored watch key, or the expressly designed comedo pressers, in the eyelids they are best removed by pressure between the thumb nails. The minute white elevations with sebaceous concretions known as milia, or the larger masses with depressed centres known as mollusca, require a slight incision made in their apices before they can be expressed without the infliction of considerable traumatism, or bruising of the skin.

Xanthelasma, the buff or yellowish-colored patches which are found at the inner part of the lids, and which affect middle-aged people, especially women, can be removed only with the knife or scissors. If they are not too large, the writer's method is to grasp them with a broad-pointed forceps and snip them off with scissors. The skin, which is very loose on the eyelids, can be slightly undermined with the same scissors, and one or two sutures will obliterate all trace of the affection, which is never anything more serious than a blemish. If the xanthelasma is large it may be impossible to excise it without sacrificing more skin than it is wise to remove. In such a case it would be better to advise the patient to tolerate the blemish, with the assurance that it will never assume a serious or malignant character.

We meet occasionally, in or under the skin of the eyelids, with horny and warty growths, lipomata, and cysts. These are easily removed, under either cocaine or general anæsthesia, leaving only small scars, which time effaces.

The skin of the eyelids is not infrequently the seat of malignant growths, the most common form being epitheliomata.

Epitheliomata seldom appear in the eyelids before middle age; indeed, most of the cases seen by the writer have occurred long after middle age. The history is alike for all cases; there has appeared a small, roundish, elevated patch or pimple, which may exist for months or even years, without causing very much annoyance. Then without apparent cause, or sometimes as the result of the patient's picking it, this patch or pimple becomes ulcerated, and refuses to heal under ordinary treatment. When these patients present themselves to the specialist the growths have passed, as a rule, into the ulcerative stage, and the patients are prepared to hear that they have malignant disease or cancer.

Even when ulceration has begun, a long time may elapse before the affection takes on a rapidly growing malignant character. There is always, in cancerous affections of the eyelids, a long period during which removal can be effected without serious deformity to the lid, and during which time removal means permanent cure. It is only after the disease has existed long enough to involve the entire structure of the eyelid, the skin, the conjunctiva, and the tissues between, when not only is there a deeply ulcerated spot, but the surrounding tissues are infiltrated, that the question of extensive operation, possibly the removal of an entire upper or lower lid, has to be considered.

It is not just to our patient to conclude hastily that a suspicious-looking ulcer of the eyelid is a malignant growth, any more than it is to defer action in the hope that it may not be malignant. We of course consider the history of the case, the age of the patient, and other points which may occur to us at the time, but the knowledge which should influence us, and which we should obtain as soon after seeing the patient as possible, is that furnished by the microscope. When we have this information, and are satisfied that a patient has malignant disease, the indications for treatment are very clear. There is but one thing to do in cancerous disease of the eyelid as elsewhere, and that is to remove the offending neoplasm; and, should we elect to remove it with the knife, we should not hesitate to remove sufficient tissue to include not only the growth itself but all infiltrated structures as well.

In removing cancerous disease of the eyelids, ophthalmic surgeons, almost without exception, prefer to resort to the knife. Some of the authorities mention the use of caustics, but the writer has been unable to find, among the various text-books on diseases of the eye, even one which recommends any other method than the knife.

It is safe, as a rule, to be guided by the advice of those who have had large experience and who are considered authorities; the exclusive use of the knife in removing cancerous growths of the eyelids is, no doubt, advocated as the result of experience. One author on diseases of the eye (Noyes) mentions the use of caustics, and his objection to their use is that they leave scars which have to be removed by operation later, while with the knife in the beginning both the cancerous growth can be removed, and the resulting deformity remedied at the same time, which is of course true. Still, a deformity of the eyelid, while it may be disfiguring, is not fatal to life, and many persons have so great a fear of the knife that, to them, death may be preferable. Then too the element of time may be a consideration. A surgeon would hesitate to perform a plastic operation for the removal of a cancerous growth and the repair of the eyelid except under general anæsthesia, and with the knowledge that his patient would remain quiet for at least two weeks following the operation, in order to secure proper healing. With the caustic treatment it would perhaps be possible for a patient to attend to his ordinary business occupation while undergoing treatment. We have in mind a case of this kind. An elderly gentleman, earning a precarious living as an insurance agent, with a large and helpless family depending on him, presented himself for treatment for an epithelioma of the upper eyelid. The disease had entered upon the ulcerative stage, and involved a spot in the centre of the lid, about 3 mm. in diameter. He was willing to submit to an operation providing it did not interfere with his work; he was unable to stop his work for even one week. In such a case it seems as if one would be justified in employing a caustic application. The resulting scar could be remedied at any time, while the epithelioma, if allowed to go on unchecked, would destroy tissue, and involve structures which could be remedied only by great sacrifice, if at all. Dr. A. R. Robinson, in "Observations in the Treatment of Cancer," concludes "that the majority of cases of cutaneous cancer can be removed with the greatest certainty and with least deformity by caustics, provided the patients are seen before the lymphatic glands are invaded." This, of course, applies to cutaneous surfaces generally, but with less force, perhaps, when the disease is in the integument of the eyelid, because of the danger to the eye itself from the caustic application. It is impossible to lay down rules which shall be invariable guides, or to give advice which is to apply to all cases indiscriminately, but the writer believes that while the use of the knife is the best method of treatment in most cases of cancer of the eyelids, there are times when caustics may be employed with advantage.

Of the affections which are situated at the margins of the eyelids, one which is not uncommon is phthiriasis, or pediculi ciliares. This affection, which is not by any means confined to unclean people, is discovered by the specialist or the family physician, and its discovery horrifies the patient and fills him with wonder. The symptoms are, itching and redness of the margins of the eyelids, and, if the condition is neglected, falling of the eyelashes. Inspection reveals the presence of the pediculi on the edges of the lids and the ova pediculi on the lashes. The treatment will consist in the removal of the offending parasites, crushing them between the thumb nails, and the application of some parasiticide. Bichloride of mercury wash must be used with caution, because of the irritating effect of this drug on the cornea. As a rule removing the parasite with the nails, as mentioned above, and the application of the yellow oxide of mercury ointment, will effect a cure in a few days.

Hordeolum is an inflammation of one of the glands of the skin of the eyelids, situated at or near the margins of the lids, and often attended with considerable swelling and tenderness, and even constitutional disturbance. There are generally a succession of the hordeola, a new one appearing as another gets well, until a dozen or more have appeared. Such a condition has often underlying it some general constitutional debility, and will require for its treatment nourishing diet, fresh air, and tonics. It is doubtful, however, if this condition of furunculosis, if it may be given this name, ever attacks and is confined to the eyelids, even when there is marked constitutional debility, unless there is added to the general derangement a local exciting cause as conjunctivitis, or some weakness or abuse of the eye itself. It is advisable, as a preliminary to the general treatment, to give attention to the local cause. If there is found to be an uncorrected refractive error in the eye, it should be corrected, and a coexisting conjunctivitis should be treated. For the hordeolum itself, nothing relieves the pain and hastens the termination of the inflammation so much as the application of hot water. Warm poultices, to hasten suppuration, which would be advisable elsewhere, should not be used for inflammations here, because of their effect on the conjunctiva. Some of the most aggravated cases of conjunctivitis the writer has ever seen have been caused by the application of flaxseed and tea-leaves poultices. Suppuration is the final outcome of a hordeolum, but it has seldom been necessary in the writer's experience to employ the knife for the evacuation of the pus, this being, as a rule, rapidly brought about by the hot applications. Spirits of camphor has been recommended to abort the inflammatory process, and while it does not invariably accomplish this, the writer has seen beneficial results follow its use.

A chalazion is a distention of a Meibomian gland with its normal secretion. This is caused by an occlusion of the duct of the gland, which may be either permanent or temporary. The distended gland sometimes becomes inflamed, when it simulates a hordeolum. Ordinarily a chalazion presents itself as a circumscribed swelling, hard to the touch, and of variable size. It may be in either the upper or lower eyelid, and not infrequently there are more than one in the same lid, and they often exist in all four eyelids at the same time. They also are caused by conjunctivitis, which may or may not be due to uncorrected errors of refraction.

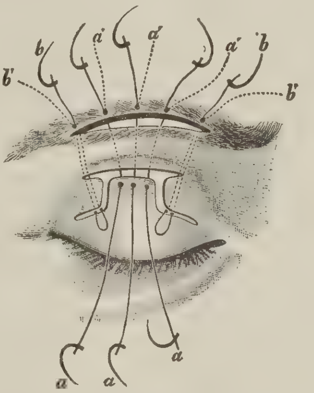

FIG. 2066.—Panas' Operation for Ptosis. (After de Schweinitz.) *a*, *a*, Sutures uniting flap to integument of brow; *b*, *b*, sutures advised by Panas to prevent possibility of ectropion resulting.

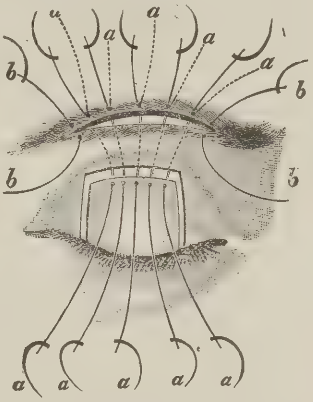

FIG. 2067.—Van Fleet's Modification of Panas' Operation for Ptosis. *a*, *a*, Sutures uniting flap to integument of brow; *b*, *b*, sutures closing extremities of incision in brow.

A chalazion may sometimes be cured by massage of the eyelids, the accumulation within the gland being pressed out through the duct. When this cannot be accomplished the cyst can be incised and the sac curetted. It has been recommended that the incision be made into the sac through the margin of the lid, or, if the incision is made through the conjunctiva, that it be perpendicular to the margin of the lid, so as to avoid cutting other Meibomian glands than the one involved. While the incisions can be made equally well in either situation, *i.e.*, through the margin of the lid or through the conjunctival surface, in some cases, in others the method to be employed will depend on the size of the tumor and its location. There is no danger of the incision destroying other glands in either case, and no evil results ever follow incisions made in either situation.

Blepharitis marginalis can be properly classed as an affection due to the same causes as hordeola and chalazia. It is possible to have blepharitis as the result of phthiriasis, but the affection commonly known as blepharitis is due either to conjunctivitis or to uncorrected errors of refraction, and more often to the latter.

Blepharitis is characterized by a redness of the margins of the eyelids, with which is associated a scaly condition, and finally by an interference with the nutrition and growth of the eyelashes.

This may be the cause of trichiasis and districhiasis, but oftener it results in the death of the eyelashes, the lids finally becoming entirely devoid of these hairs.

The treatment of this condition is local, and consists in applications to the eyelids themselves, and the correction of errors of refraction with suitable glasses. It is not unusual to see stubborn cases of blepharitis, which resist treatment, or after frequent relapses, finally become cured and remain so, when properly fitted glasses have been adjusted and worn.

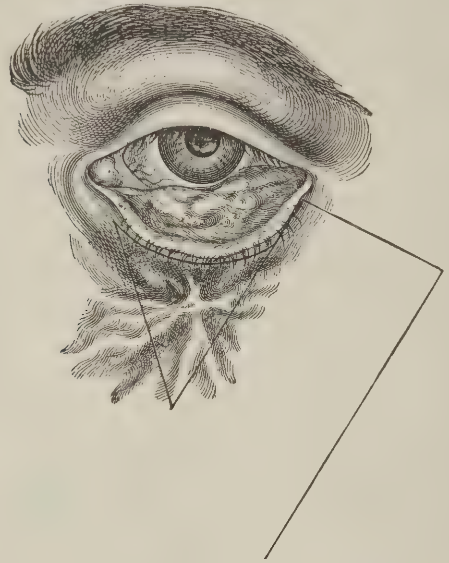

FIG. 2068.

Pagenstecher's ointment (Unguentum hydrargyrum oxidum flavum) is the local remedy generally employed in this affection. It is often made too strong, when it is very irritating; the greatest care should also be exercised in selecting a proper base, and having it thoroughly mixed. The ointment should never be made stronger than one grain to the drachm (except as a parasiticide) and the best base to employ is vaseline. Fatty bases, as cold cream, simple cerate and others—which contain lard—decompose; the fatty acids alter the chemical nature of the yellow oxide, making, as before mentioned, an irritating ointment. This is an important consideration which should not be forgotten.

Trichiasis and districhiasis, together with entropion, are the results of inflammatory affections of the conjunctiva, such as chronic conjunctivitis and chronic trachoma. As a result of cicatrization of the conjunctiva, the tarsal cartilage becomes curved, and the eyelashes, instead of curving outward, curve inward and sweep over the eyeball. The eyelashes can be pulled out, and for this purpose specially devised forceps have been made, called epilation forceps. The relief afforded by this treatment is only temporary and incomplete. The eyelashes grow again, and even if pulled again the inner edge of the margin of the lid rubbing over the eye keeps up the irritation. The radical cure of this condition is by operation, and the writer prefers the operation in which a wedge-shaped piece of the tarsal cartilage is removed. The results obtained from this operation are good and lasting. It is performed as follows: The patient is anæsthetized (which, by the way, is best in all plastic operations about the eyelids). Cocaine gives satisfactory results only in operations on the eye itself. An incision is made through the skin, parallel with and about 2 mm. from the tarsal margin, extending down to the tarsal cartilage. Pushing the muscle and connective tissue aside, the operator should expose the whole surface of the cartilage and should carry the incision straight down, in such a manner as to involve almost the entire thickness of the cartilage. Sometimes the knife will go through the cartilage, but this does no harm. A second incision is then made in the cartilage, about 2.5 mm. from the first, tapering to and meeting the first incision at the ends. This second incision, instead of going straight down through the cartilage, is made obliquely, and meets the first incision not only at its ends, but at the bottom as well. The wedge-shaped piece of cartilage thus formed is removed. A central suture is then passed through the lower edge of the incision in the skin, and through the lower edge of the incision in the cartilage. It is then carried through the upper part of the cartilage, passing over the groove made in the cartilage by the removal of the wedge, and finally brought down through the upper edge of the cutaneous incision. Two more sutures like the first are inserted, one on either side of the central suture, and as many more as the operator thinks necessary. When these sutures are tied the margin of the lid and the lashes will be permanently everted. This operation can be employed only in the upper lid. Operations for the relief of entropion of the lower lid are not nearly so satisfactory. The cartilage in the lower lid being so small, the best we can do is to remove an elliptical piece of skin, which will give relief, often lasting a long time.

Ectropion is the result, as a rule, of cicatricial contractions of the skin of the eyelids, and requires for its relief a plastic operation. We will consider these operations under wounds and burns. There are two forms of ectropion of the lower lid, however, one due to chronic conjunctivitis, in which the hypertrophy of the conjunctiva and the underlying connective tissue everts the lid, and the other the result of senile change, which can be relieved by applications of alum or sulphate of copper to the conjunctiva.

Blepharophimosis, a narrowing of the palpebral orifice, which may be congenital or the result of chronic trachoma, can be remedied by the operation known as cantholysis, or canthotomy. A wire speculum is inserted between the eyelids, and the external canthus put on the stretch. With straight and strong scissors the external canthus is then divided, both mucous membrane and integument, back to the margin of the orbit. The mucous membrane is then lifted with forceps and the external cantha lligament divided. The mucous membrane at the bottom of the wound thus made is united to the integument and at the sides as well. A vaseline dressing is applied, and the stitches are removed in three or four days.

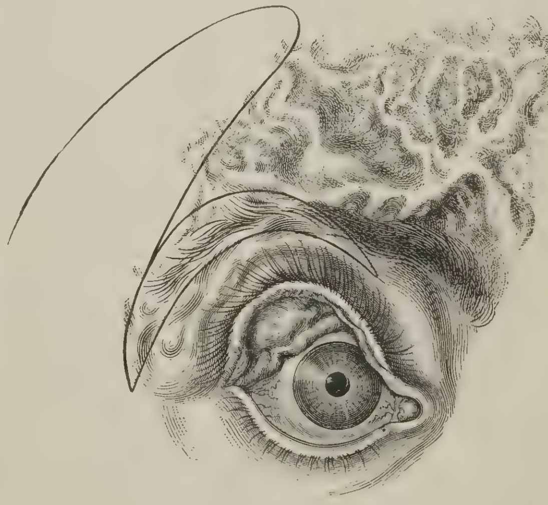

FIG. 2069.

Canities is a name given to white eyelashes, of which there may be one or more in an eyelid whose other lashes are of darker color, even black. This condition may be congenital, or the result of some interference with the nutrition of the cilia. Nothing can be done for this except epilation, which may be resorted to if the white lashes are not too numerous.

Interference with the motility of the eyelids, due to paralysis or other causes, is of frequent occurrence and demands attention. The most annoying and dangerous to the patient's sight, and which will often baffle the physician, is the inability to close the eyelids in paralysis of the seventh nerve. In this condition the eyelids are open when awake and when asleep, and the eye frequently becomes irritated and even ulcerated and destroyed, from this constant exposure to wind, smoke, and irritating substances generally. If the paralysis is transitory, it may only be necessary to protect the eye with a bandage or with a shield; when the paralysis becomes permanent, however, as sometimes happens, it may be necessary to resort to operative procedure, and to close the eyelids by suturing the upper and lower lids together, first denuding the edges.

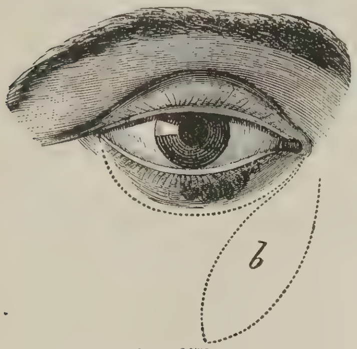

FIG. 2070.

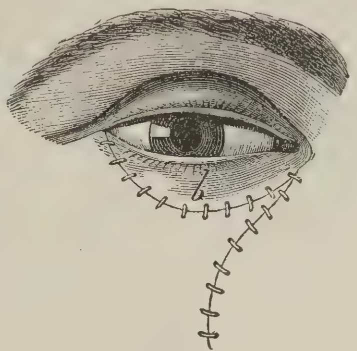

FIG. 2071.

The opposite condition to paralysis of the seventh nerve is the inability to open the eyelids when the third nerve is paralyzed. This condition is known as ptosis, and when due to paralysis of this nerve is generally acquired, and amenable to treatment by drugs. Paralysis of the third nerve—the motor oculi communis—may be due to intracranial growths, when it becomes a very serious condition; in the majority of cases, however, this paralysis is due to acquired syphilis, and responds quickly to antisyphilitic treatment. We do occasionally meet patients in whom ptosis due to this cause persists, even after prolonged treatment, and when we have every reason to believe the syphilis has been cured, and then it is necessary to resort to operative treatment if we desire to remedy the defect. We may not consider it advisable to remedy this deformity always, as we shall consider later.

Ptosis may be due to other causes; it may be congenital or it may be the result of chronic conjunctivitis or trachoma.

In congenital ptosis there may be associated with the paralysis, or imperfect development of the levator palpebræ superioris, paralysis or imperfect development of some of the other muscles of the eye, notably the superior rectus. Any or all the recti muscles may be involved, generally one of those supplied by the third nerve. The writer has seen a patient in whom not only were the muscles supplied by the third nerve affected, but the external rectus, which receives its motor power from the sixth nerve, was also involved. When the superior rectus is involved the eye will be rotated downward, and when the internal alone is affected the eye will be drawn outward. The recti muscles are generally affected in syphilitic ptosis, and frequently are not affected in congenital ptosis. They are not involved when the ptosis is due to inflammatory conditions of the conjunctiva. To overcome the ptosis by operation when any of the recti muscles are involved may, by exposing a deviating eye, produce an annoying diplopia, and this will have to be considered before advising such an operation.

In trachoma, after the disease is cured, a drooping of the upper eyelid will sometimes persist, which may necessitate an operation, and it is in cases due to this cause that our best results are often obtained. Various operations have been devised to overcome this deformity, and the results have been until recently rather unsatisfactory. The levator palpebræ superioris muscle, which raises the upper eyelid, arises in the orbit, from the lesser wing of the sphenoid bone, directly in front of the optic foramen. Its insertion is in the upper eyelid, to the convex margin of the tarsal cartilage. Its action is to draw the lid upward and backward. In the absence or imperfect development of this muscle, and when it is inoperative because of some affection of the nerve supplying it with motor power, operators have endeavored to make the occipito-frontalis muscles—the anterior portion of which is intimately adherent to the skin of the forehead—take the place of the levator. The results obtained by Pagenstecher, De Wecker, and others, have been only partially satisfactory, the effects not being permanent.

The operation devised by Panas has given satisfactory results, which have been permanent. The operation is, however, somewhat complicated and difficult to perform. The writer has modified this operation, making it extremely simple, and the results in his hands, and in the hands of other operators as well, have been generally successful. It is performed as follows: The patient being anæsthetized and the brow shaved, the face and forehead are thoroughly cleansed with a bichloride wash. An assistant then inserts under the upper eyelid a horn shield, and with his free hand steadies the skin of the brow, as directed by Panas. The operator then makes in the upper lid, at or slightly above the upper convex margin of the tarsal cartilage, an incision which commences at the inner side and includes the middle third of the lid. From the inner extremity of this incision another is made extending down to the ciliary border, and a third is made in like manner from the outer extremity of the first. The integument enclosed by these three incisions is dissected from the underlying tissue, down to the ciliary border of the lid, making a flap. A final incision is made in the brow, parallel with the first incision in the lid, but slightly longer. The integument between these two horizontal incisions is then undermined in such a manner as to make a bridge. The parts are carefully cleansed, the flap is passed up under the bridge and secured by stitching its upper margin to the upper margin of the incision in the brow. This is accomplished by means of five interrupted silk sutures. The outer and inner extremities of the final incision (*i.e.*, the outer and inner extremities of the incision in the brow after the flap has been stitched in

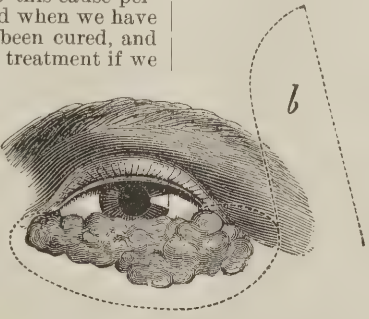

FIG. 2072.

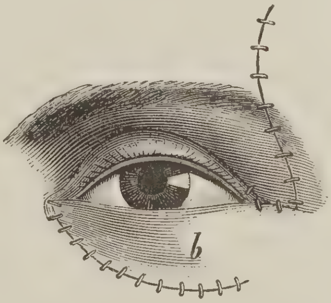

FIG. 2073.

place) are sutured, and the whole is covered with sterilized vaseline and bichloride gauze, and bandaged. The bandage is not to be removed for two days, after which it should be removed daily for a week, when the stitches can be taken out and the dressing discontinued. The epithelium of the flap becomes macerated and exfoliates, and the true skin unites with the under surface of the bridge, of which it becomes a part, or perhaps disappears.

It is not well to make the flap too narrow; it may even be made to include more than the middle third of the lid. Its length should vary with the degree of ptosis to be overcome. Sometimes after the operation the eyelids may not close in sleep, but this is only temporary. Another point to be considered is the tendency of the bridge to curl, causing a scar in the brow. This can be avoided by including the upper edge of the bridge in the sutures which unite the flap to the skin of the brow. The epithelial surface of the flap may also be scarified slightly, to hasten its union with the under surface of the bridge.

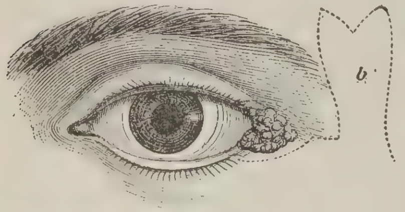

FIG. 2074.

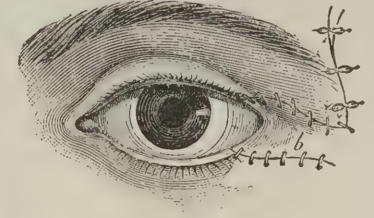

FIG. 2075.

This modification differs from the original operation of Panas in that the lines of incision are straight, and extend only through the integument, whereas Panas recommends that they extend down to the periosteum, which must necessitate a longer time in healing, and adds to the operation the danger of wounding deeper tissues, as, for example, the supra-orbital nerve.

The object of this operation is to make the occipito-frontalis muscle take the place, or do the work, of the levator of the lid; the flap, uniting by first intention with the upper edge of the incision in the brow, becomes a part of the skin controlled by the contractions of the occipito-frontalis, quite as much as it would if the incisions were deeper. The two lateral sutures advised by Panas to prevent ectropion are not necessary in the modified operation (see Figs. 2066 and 2067).

Blepharospasm is a spasmodic contraction of the orbicularis muscle, present in inflammatory conditions of the eye or the conjunctiva. Occasionally, when it persists and interferes with the treatment of the underlying inflammatory condition, it may be necessary to perform the operation known as canthotomy, which we have already mentioned. Blepharospasm may also be associated with the affection known as tic douloureux. If the cause of the tic can be ascertained, the treatment will suggest itself. In some cases nothing seems to afford relief, and we are compelled to resort to operative procedure, namely, stretching or dividing the trigeminus, or even extirpation of the Gasserian ganglion. Even these extreme measures often fail to give relief. The writer now has a patient under observation who has facial tic with blepharospasm, and who has become an opium victim, whose ganglion was removed many years ago. When last seen this patient was taking sixteen grains of morphine sulphate daily to relieve the pain.

Nictitation, or winking of the eyelids, is due often to local troubles, as conjunctivitis and trachoma. Even uncorrected errors of refraction may be the cause. When due to these conditions, the removal of the cause will effect the cure. At times a general nervous derangement seems to be the cause, when tonics are indicated. One must not expect, however, to cure all these cases, especially when the patients are markedly neurasthenic.

Ecchymosis of the eyelids occurs as the result of traumatism or of paroxysms of coughing, as in whooping-cough in children and in chronic bronchitis in older persons, or it may occur without apparent cause.

When ecchymosis of the eyelids occurs in elderly people without apparent cause, we should be suspicious of atheroma of the blood-vessels, and the interior of the eye should be examined for hemorrhages. We should also bear in mind that a hemorrhage of this character may be the precursor of cerebral hemorrhage. Extremely hot applications are recommended by some authorities as giving the best results in ecchymoses due to traumatism, while others recommend iced applications. The writer prefers the ice for the reason that it is easier to apply, and is therefore likely to be more efficiently applied than hot applications. Either very hot or very cold applications, if resorted to as soon as the traumatism is received, will prevent extensive discoloration of the skin, but neither will accomplish much if the application is delayed. Warm fomentations are not to be advised.

Aside from painting the integument of the eyelid to hide the discoloration, time is the best remedy.

Almost every conceivable injury which can happen to the integument of the body elsewhere can occur about the eyelids. The writer has seen a patient whose eyelid was nearly torn off in a street fracas, and has also seen an eyelid split by the branch of a tree, and by being caught on a butcher hook. Any of these injuries can be repaired while still fresh by carefully cleansing the parts and bringing them together, retaining their apposition with sutures. Larger and older wounds may require extensive plastic operations, the extent and nature of which will depend on the wound.

Burns of the eyelids are not uncommon, and especially gunpowder burns. It is well in powder burns to remove, as thoroughly as possible, all particles of powder which may be in the skin. The only way in which this can be accomplished is to pick the particles out, one at a time, with a forceps or spud. It may take hours of patient work to do this, but the result amply repays the time so spent.

In many, perhaps most, powder burns, only the epithelium of the lid will be injured. When this is the case, it is only necessary, after the powder specks have been removed, to apply a bichloride vaseline, bandage the parts, and keep them clean.

Where more than the epithelium has been injured, it may be necessary to stitch the lids together and resort to skin grafting in order to prevent the deformity which the cicatricial contraction will produce. The method of skin grafting which gives the best results is the Thiersch method.

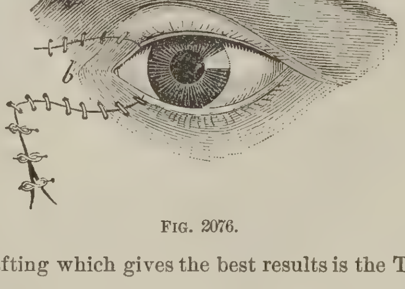

FIG. 2076.

The repair of damages to injured eyelids, and the relief of deformities occasioned by cicatricial contraction of wounds caused by injuries and burns, will give opportunity for the display of all the ingenuity and skill an operator may possess.

It is impossible to lay down definite rules as to when deformities are to be remedied by skin grafting, and when it may be necessary to resort to extensive plastic operations and the transplantation of large pieces of skin from the forehead and face. As a rule, it is better to reserve the Thiersch method for those cases in which the damage is so extensive that it is impossible to secure enough sound skin from the face or forehead to repair the damage—a condition sometimes found after scalds and burns. There may be times when both the transplantation of skin and the Thiersch method may be employed.

An eyelid, or both eyelids, on one or both sides, may be required to be replaced by skin taken from the forehead or cheek, or even from some other part of the body, as the arm. The necessity for taking a flap from the arm happens infrequently, and can be considered only when a cicatricial condition of the face or forehead makes it impossible to secure it from these parts. To remove a large piece of skin in toto and transplant it on some other part of the body would result, as a rule, in the speedy death of the part so transplanted, unless it remained attached to its original situation by a pedicle. In order to transplant a flap of skin from the forearm to the eyelid, and still retain the attachment of the flap to the forearm by a pedicle, would necessitate bandaging the arm to the head in a firm, immovable position for at least forty-eight hours. This has been done,—indeed, such a transplantation has been successful without a pedicle,—the pedicle being severed when the flap has united. Generally, however, it is possible to obtain enough sound skin from the face, except, as we said above, when there is extensive cicatricial contraction. A few general rules are necessary in order to secure a good result in plastic operations. When the margins of the lids are widely separated or everted, by cicatricial contraction, the first step must be to divide the cicatrices and bring the lids together, holding them in proper position with sutures. Every contraction which draws in any way on the margins of the lids should be freely loosened. We shall then have exposed the whole denuded surface which it is necessary to repair.

The next step must be to secure the flap with which to cover this denuded surface. Undoubtedly we have selected the spot from which this is to come before we began our operation, and have been influenced in our choice by the necessity of obtaining a strip of skin large enough to fill in the denuded surface, from a place where it is possible to secure also a healthy pedicle. The flap should be as nearly as possible devoid of cicatricial tissue, and it is even more important to have the pedicle of healthy skin. We have seen transplanted flaps thrive when they included superficial cicatrices, but when it is possible to utilize only healthy skin it is better to do so.

The flap should be large enough to prevent any tension on it or the parts to which it is sutured, when *in situ*, and it should be as free as possible from adipose tissue. The pedicle by which it retains its continuity with the surrounding tissues should be as broad as it is possible to make it, and should lie as flat as possible. A slight twist in the pedicle is not fatal to a good result, but any twist which is likely to interfere with the circulation of blood in the flap is to be avoided. In attaching the flap to the skin with which it is desired to secure union, fine iron-dyed black silk is to be preferred. The sutures should be close together, should not be very deep, and should not be tied too tightly. The writer does not recommend the use of harelip pins, believing that when they are necessary there is apt to be too great a tension on the flap to permit of union by first intention. A fatal mistake in plastic operations is to unite the parts before all bleeding has ceased. Severed arteries which persist in bleeding despite torsion should be tied with catgut ligatures, and the oozing of capillaries can be arrested by the application of hot water, or by gentle pressure; we must not use so much hot water that we destroy tissues and cause sloughs. The writer believes in the frequent washing of the parts with a weak bichloride solution during the operation.

After the parts are stitched in place, the spot from which the flap was taken must be repaired. This can be easily accomplished anywhere about the face, because of the looseness with which the integument is applied, by freely undermining the edges and bringing them together. Here is a consideration which must be taken into account when choosing a site from which to take a flap. We must be sure that the bringing of the parts together after the flap has been removed will not create a tension on the edges to which the flap is stitched after it is in its new position.

Flaps should not be taken from the cheek of a man whose beard is heavy and placed on the eyelid. The writer has seen this done, the flap producing a thick growth of hair which was annoying as well as disfiguring.

When the flap has been stitched in place, and the parts have all been adjusted to our satisfaction, a dressing of bichloride gauze should be placed over the wounds and a bandage loosely applied. This can be removed in two or three days, the parts cleansed if necessary, and the dressings reapplied. It is desirable to disturb the wounds after plastic operations as little as possible. The stitches can be removed, a few at a time, in from three days to a week. (Figs. 2068–2076.)

Epicanthus is a congenital defect characterized by a flatness of the bridge of the nose, and by the presence of crescentic folds of skin over the inner canthi. The defect is remedied by removing an elliptical piece of skin from the bridge of the nose and bringing the parts together. (Fig. 2077.)

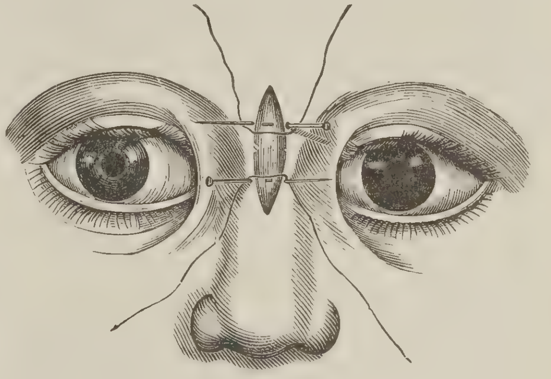

FIG. 2077.

Coloboma of the eyelid may also be congenital, and is remedied by paring the edges of the coloboma and sewing them together.

Nævus, another congenital defect, assumes a variety of forms. A simple reddened spot which varies in the intensity of its hue, often is seen in the eyelids of the newborn infant. Frequently these spots disappear in the first few months of life. Sometimes an intensely livid spot may cover the whole lid, or even the whole side of the face as well; when marked, these spots do not disappear, and very little can be done for them. Sometimes the distorted and enlarged blood-vessels may form distinct and irregular tumors. Treatment will be excision by means of the knife, or destruction of the blood-vessels by means of hot needles plunged into them. At times it may be possible to destroy a telangiectatic tumor by tying of the blood-vessels. The variety of these tumors renders it impossible to go into their treatment in detail in this article. Sometimes the results obtained are very satisfactory, and at other times, unfortunately, they are not satisfactory.

Frank Van Fleet.

EYE-STONES.—The opercula of certain species of gastropod mollusks. These organs are horny or calcareous valves, situated in the so-called foot of the mollusks, and serving to close the apertures of their shells when the animals withdraw themselves into them. They are of different shapes and variously developed in different species—in many species they are absent altogether. Those which are used as eye-stones are hard, stony, plano-convex bodies, about as large as split peas, 0.005

to 0.01 metre in diameter ($\frac{1}{6}$ to $\frac{1}{3}$ inch), rather longer than broad, with a smooth but rather dull plane, and a very smooth and shining, convex surface. The former has an excentric white nucleus, from which a brown, right-handed, spiral line reaches the edge in about two turns; the outer portion of this surface is variegated with light-brown markings, and finely striated with numerous lines running in the opposite direction. The convex surface is slightly asymmetrical, the thickest point being nearly opposite the nucleus of the spiral just mentioned. It is brownish flesh-colored in the centre, shading to white at the margin. Many specimens are much worn by the action of the sea; these are white as coral, and the spiral structure is difficult to make out. Eye-stones are composed mostly of lime carbonate, and perform entertaining movements occasioned by the discharge of carbonic acid from the surface when placed with the flat side down, in a vessel containing dilute acids. They have long been a popular resource in treating foreign bodies in the eye, for which one is placed under the lid, where it is carried around by the movements of the eye. When it comes in contact with the mote, this is carried along with the "stone" by capillary attraction, and is finally expelled with it. They are a clumsy means of doing what a small amount of skill will accomplish with far more certainty, and are deservedly nearly obsolete. The belief that they are alive and move themselves about in the eye, until they "find" the mote, is a popular fallacy. The demand for them now is very limited, and confined to the ignorant. The supply is also small and uncertain, those of this port (Boston) coming mostly in little lots from sailors who bring them from the Bahamas and elsewhere, as curiosities or private ventures. "Crab's-Eyes," lenticular concretions found in the lining membrane of the stomach of the crawfish, look much like eye-stones, and are described for them by several authors. The description just given will easily distinguish them.

W. P. Bolles.

EYES, ARTIFICIAL. See *Artificial Eyes.*

FACIAL NEURALGIA. See *Neuralgia.*

FACIAL PARALYSIS (Bell's Palsy).—Etiology.—In a large proportion of cases, peripheral facial paralysis is the result of so-called rheumatic influences, such as exposure of one side of the face to a draught, working in a damp room, or sudden chilling of the body while in a state of perspiration.

The disease may also be produced by a large number of organic lesions, which may be situated in the cranial cavity, in the course of the nerve through the Fallopian canal, or after its exit from the mastoid foramen.

The lesions within the cranial cavity which may give rise to this disease include basilar meningitis, tumors or exostoses situated at the base of the brain, syphilitic lesions in this situation, and aneurisms of the vessels of the base of the brain.

Within the Fallopian canal the paralysis may be the result of caries of the petrous portion of the temporal bone, otitis media, tumors which extend into the canal from adjacent parts, fracture of the base of the skull extending through the temporal bone, syphilitic deposits within or near the nerve, or an accumulation of wax in the external auditory canal.

After the exit of the nerve from the mastoid foramen, the paralysis may be produced by direct violence to the nerve (a slap on the face, fall, etc.), pressure upon the nerve, for example, the pressure of the forceps during parturition (a few cases have also been reported in which facial paralysis occurred during difficult and tedious labor, although the forceps had not been used), extension of inflammation to the nerve from adjacent parts (tuberculous abscesses of the glands situated near the angle of the jaw, parotitis, incised wounds during operations in this region, etc.). A case has also been reported in which the disease was produced by leukæmic infiltration of the nerve.

In comparatively rare cases facial paralysis follows certain of the infectious diseases, such as diphtheria, smallpox, erysipelas, typhoid fever. Gowers and others report cases of facial paralysis after tonsillitis, and Halschek has seen a case of double facial paralysis after mumps. This symptom has also been observed as a part of multiple neuritis. Many writers regard the disease as usually infectious in its origin. Several cases have also been reported in which the disease occurred during the secondary stage of syphilis, and was attributed to the direct action of the syphilitic virus. von Burski reports two cases in which the paralysis developed ten weeks after syphilitic infection, during the roseola.

The disease is more frequent in males than in females. It occurs very rarely during childhood and infancy.

Some writers believe that there may be a neuropathic predisposition to the disease. Browning reports the following case which bears on this point: A girl had facial paralysis after a cold; a few years later an older sister had a similar attack. The younger sister had two daughters; one of these had facial palsy after a cold, the other had a similar attack during childbed, from sleeping at an open window.

Clinical History.—Facial paralysis is almost always confined to one side of the face. In very rare cases it is bilateral (diplegia facialis), and in such cases the paralysis sometimes appears on the two sides at different times. Sometimes a similar cause operates upon both facial nerves (usually the so-called rheumatic influences); sometimes one lesion acts upon one nerve, an entirely different lesion upon the other nerve. Diplegia facialis is also a symptom of certain bulbar affections, but the consideration of the symptoms which distinguish the peripheral from the central variety will be reserved for the section on diagnosis.

Ordinary peripheral facial paralysis may begin suddenly, or it may be preceded for some time by a feeling of fulness and puffiness in the face, and by peculiar gustatory sensations on the affected half of the tongue. Rare prodromes consist of tinnitus aurium, dizziness, and pain in the face. Gowers has observed fever and temporary albuminuria. In Hoffman's case the paralysis was preceded by severe pains in the right side of the neck and face, and was attended by unconsciousness. Hence this writer believed that the attack was constitutional in origin. The paralysis may occur suddenly and completely in all branches (in rheumatic cases from a couple of hours to one or two days from the action of the exciting cause), or it may spread from one group of muscles to another (when it is the result of compression by a slowly growing external tumor or other lesion which acts in a similar manner). In the majority of cases all the muscles are affected in an approximately equal degree.

The appearance of the face is well shown in Fig. 2078. The patient, whose photograph is here shown, was directed to contract all the muscles of the face, but, as is evident from the illustration, power over the left facial muscles is entirely lost. The left eyebrow is slightly elevated, the palpebral fissure is enlarged, the naso-labial fold is effaced, the angle of the mouth droops slightly and is drawn nearer to the median line (this is observed even when the face is in repose), the mouth is kept a little open on this side, and the tip of the nose deviates slightly to the healthy side.

A patient suffering from complete facial paralysis is unable to wrinkle or corrugate the brow, on account of the paralysis of the frontalis and corrugator supercilii muscles. On making a vigorous effort to close the eyelid the globe is rolled upward and inward (or rarely outward), so that often only the sclera remains visible. But the upper lid descends a little, even when the nerve appears to be completely paralyzed. The descent of the eyelid has been attributed to a partial relaxation of the levator labii superioris, but it must be confessed that this explanation is not very satisfactory. On account of the paralysis of the orbicularis palpebrarum the puncta lachrymalia are no longer kept applied to the globe, and consequently the tears cannot make their way into the lachrymal canal and nasal cavity. Hence, the patients suffer from overflow of tears. The paralysis of the orbicularis also prevents winking and the closure of the eye during sleep. The consequent irritation of the eyeball may give rise to conjunctivitis and keratitis, though this does not happen very often. The lower lid may become everted.

The ala nasi on the paralyzed side cannot be distended so vigorously as on the healthy side, and hence smell is somewhat impaired. This impairment of smell is increased still further owing to the fact that diversion of the tears from the nasal cavity causes dryness of the Schneiderian mucous membrane.

The angle of the mouth droops a little, and is drawn slightly toward the median line. This phenomenon is increased upon bringing into play the muscles which are inserted into the opposite angle of the mouth, as in the act of laughing. The lips cannot be closed on the affected side, and hence whistling is rendered impossible. The pronunciation of labials may be interfered with, but in many cases articulation is undisturbed. The cheek on the paralyzed side flaps loosely when the patient attempts to puff it out. Mastication is also interfered with to a certain extent, on account of the paralysis of the buccinator muscle. The food is apt to accumulate between the cheek and teeth, and must be dislodged frequently by the patient's finger. In a considerable proportion, perhaps the majority, of cases taste is impaired upon the anterior third of the tongue on the paralyzed side, and sometimes the patient complains of peculiar subjective sensations in this locality. This is owing to the fact that the chorda tympani nerve, which supplies the anterior third of the tongue with gustatory fibres, joins with the seventh nerve during its course through the Fallopian canal. Some doubt still attaches, however, to the anatomical and physiological relations of this nerve.

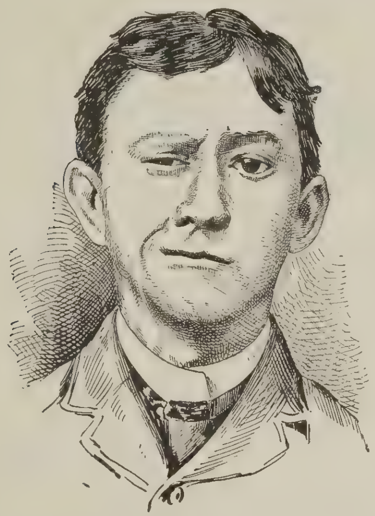

FIG. 2078.—Well-marked Facial Paralysis of the Left Side. (From a photograph taken at the moment when the patient was told to contract all the muscles of his face.)

The tongue is protruded in a straight line, but, on account of the displacement of the oral fissure toward the healthy side, there is an apparent deviation of the organ toward the paralyzed side.

In certain cases (*vide* the section on diagnosis) the palate and uvula are found to be paralyzed. Upon inspection the paralyzed velum palati is seen to hang lower than on the opposite side, and the uvula may be deflected to one or the other side (the latter phenomenon is sometimes observed in healthy individuals). These parts also remain almost motionless during phonation, or when reflex action is excited by irritation of the fauces. Deglutition is also interfered with to a certain extent, so that the patients often swallow the wrong way. Some writers deny the occurrence of an affection of the velum during facial paralysis. Lermoyez comes to the conclusion that the velum is innervated almost entirely by the pneumogastric.

As a rule, the sensibility of the integument remains unaffected, but in a few cases the patients complain of a feeling of numbness of the skin. In these cases, however, we have never been able to detect any objective evidences of disturbed sensation. The symptom in question is probably the result of an implication of some of the recurrent fibres of the trigeminus in their course along the facial nerve.

Hearing may be affected, sometimes as the result of the lesion which gave rise to the paralysis, sometimes as the result of the paralysis itself. In the latter event the patient suffers from hyperacusis (also called oxyokoia), *i.e.*, increased sensitiveness to auditory impressions. This has been explained by the paralysis of the stapedius muscle (which is supplied by the facial nerve), and the consequent predominance of the action of the tensor tympani (supplied by the fifth nerve). Herpes zoster is sometimes seen. Klippel distinguishes febrile zoster (infectious disease) combined with facial paralysis from the accidental herpes eruptions, which, like the accompanying facial paralysis, are due to definite lesions of central parts or of the peripheral nerve. In the former event, the eruption may be present only on the paralyzed side of the face or also in other parts, or it may not be located in the face at all. Remak reported a case, complicated with zoster of the anterior two-thirds of the tongue on the paralyzed side. The zoster recovered during the first week of the paralysis.

In some cases the muscular and nerve irritability remains normal throughout the course of the disease. Such cases usually recover spontaneously and with great rapidity.

Many cases present various stages of transition from normal electrical excitability to the complete form of degeneration reaction. Indeed, we find not infrequently that one case presents various conditions of electrical excitability in different muscles and branches of the nerve.

If the patient does not recover from the disease, the electrical irritability of the muscles gradually diminishes, and is finally abolished.

Experimental investigations have shown that the degeneration reaction is the result of certain lesions of the paralyzed nerve and muscles. When the degeneration reaction is at its height, it is found that the axis cylinder has disappeared, the medullary substance has undergone fatty degeneration, and the nuclei of the sheath of Schwann are increased in number; the interstitial connective tissue and nuclei undergo proliferation. At the same time the muscular fibrillæ are diminished in size and their nuclei increased in number; the transverse striæ are less distinct or absent, and the interstitial connective tissue is increased in amount. If recovery ensues all these changes gradually disappear.

Flatau reports a case of left facial paralysis due to chronic tuberculous otitis media, with total degeneration reaction (D.R.). Death occurred within a year from tuberculosis. The central portion of the nerve was found degenerated in its intramedullary and basal course; the cells of the left facial nucleus were swollen, misshapen, etc. The degeneration extended to the intranuclear facial fibres, the left ascending root, the efferent root, etc. These findings show that Waller's law of degeneration is no longer tenable as first laid down. The peripheral motor nerve is dependent on the cell, but is only part of a coherent, indivisible entity (the neuron), and the destruction of any part of this unit leads to changes in the entire neuron.

In another case of paralysis from middle-ear disease, Darkschewitsch and Tichonow found, on autopsy, the neurilemma unaffected; the lesions were those of purely parenchymatous neuritis.

In a few cases recovery is not complete, and spasms and contracture of the muscles are left over as sequelæ. These conditions may exist separately, but they are usually associated with one another. The spasms consist of short, quick contractions of the muscles, occurring irregularly, and very much resembling facial tic. These spasmodic movements are unattended with pain and are often unnoticed by the patient.

Contracture is observed particularly in the levator palpebræ superioris alæque nasi and zygomatici muscles, and causes retraction of the angle of the mouth upward and outward. It thus tends to overcome the original deformity produced by the paralysis. When the contracture is very marked, the deepening of the naso-labial fold to which it gives rise may create a deceptive appearance of paralysis upon the opposite side of the face. An error in diagnosis may be obviated by directing the patient to laugh, whereupon it becomes evident that the contractured muscles remain motionless, while those on the healthy side contract normally.

Gowers thinks it probable that contractures and clonic spasms are due to changes in the facial nucleus, caused by continued interruption in the nerve tracts and constant irritation of the centre during attempts to move the facial muscles. The cell resistance is diminished and hence the cells react with abnormal facility.

If complete paralysis of the muscles remains permanent, the muscles will undergo atrophy, so that the affected half of the face looks smaller than the other side.

Oppenheim has described a rare combination of peripheral facial paralysis with hysterical symptoms, viz., hysterical hemianæsthesia on the same side. The paralysis persisted but the hemianæsthesia disappeared in a short time.

In diplegia facialis the face presents a remarkable appearance inasmuch as it is absolutely devoid of expression, and even the most violent emotions are experienced by the patient without the slightest change of countenance. The lower lip droops, and saliva is constantly flowing from the mouth. Articulation and deglutition are interfered with to a very marked degree.

Diagnosis.—The differentiation of peripheral from central facial paralysis is usually quite easy. In the latter affection the muscles of the forehead and eyelid are very slightly involved. As a rule, however, on directing the patient to close only the eye on the paralyzed side, it becomes evident that this is done with less vigor and promptitude than on the healthy side. The affected muscles present no changes of electrical excitability, however profound the paralysis may be. It will also be noticed that the voluntary and the reflex contractility of the paralyzed muscles are often in marked contrast to one another, the latter being much greater than the former. Furthermore, the clinical history of the two affections is usually decisive. In the cerebral variety the facial paralysis is almost always associated with paralysis in some other part of the body, usually of the arm and leg upon the same side. In addition, cerebral facial paralysis generally develops after an apoplectic seizure, which is usually accompanied by unconsciousness.

In a certain proportion of cases the disturbance of gustation on the anterior portion of the tongue, the paralysis of the velum palati and uvula, and the history of a previous disease which may have produced a lesion of the seventh nerve, will aid us in clearing up any possible doubt in diagnosis.

In rare cases, however, facial paralysis produced by lesions of the pons Varolii presents most of the characteristics of peripheral facial paralysis. If the lesion is situated in the lower half of the pons, the facial paralysis is associated, as a rule, with hemiplegia of the opposite side of the body. When the lesion is situated in the upper half of the pons (before the decussation of the seventh nerves), the face and limbs are paralyzed on the same side of the body. The frontalis and orbicularis palpebrarum may be entirely paralyzed, as in ordinary peripheral paralysis, and, in addition, there may be marked changes in the electrical excitability of the facial nerve and muscles. But a mistake in diagnosis is usually obviated by the presence of other symptoms of a pons lesion, such as contraction of the pupils, marked difficulty in swallowing and articulation, and paralysis of various cerebral nerves (trigeminus, abducens, hypoglossus), etc.

After the diagnosis of the peripheral character of the disease has been made, we should also endeavor to determine its location more accurately. As a rule, this can be done with great certainty on account of the peculiar anatomical relations of the nerve.

If the lesion is situated above 5 (Fig. 2079), the patient will suffer from paralysis of all the facial muscles, of the uvula and velum palati, and from disturbances of hearing, but gustation will be unimpaired. This is owing to the fact that the chorda tympani nerve enters the facial nerve, in all probability, at the ganglion geniculatum through the petrosus superficialis major nerve, *psm* (from the trigeminus). The chorda tympani leaves the facial nerve between 2 and 3, *cht*, and then joins the lingual branch of the trigeminus.

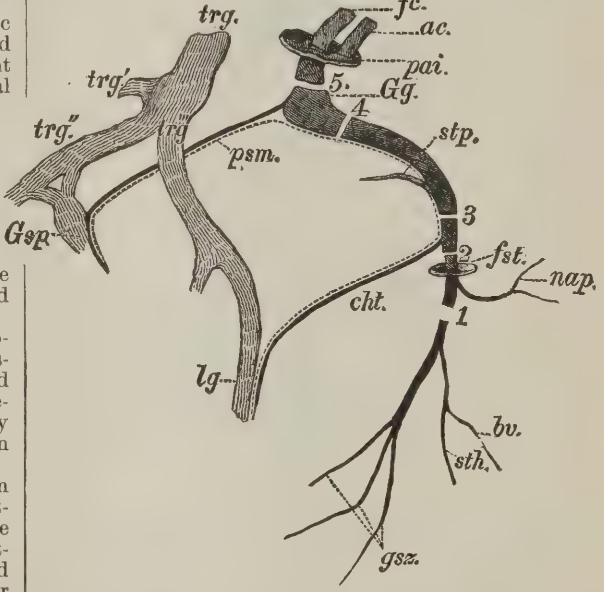

Fig. 2079.—Schematic Representation of the Ramifications of the Facial Nerve. (After Eichhorst.) *fc*, Trunk of facial nerve; *ac*, trunk of acoustic nerve; *pai*, internal auditory foramen; *gg*, ganglion geniculatum; *psm*, nervus petrosus superficialis major; *stp*, nervus stapedius; *cht*, chorda tympani; *fst*, styloid foramen; *nap*, posterior auricular nerve; *bv* and *sth*, nerves to the digastric and stylo-hyoid muscles; *trg*, *trg'*, *trg''*, *trg'''*, trunk and branches of the trigeminus; *gsp*, spheno-palatine ganglion; *lg*, lingual nerve.

If the lesion is situated between the ganglion geniculatum and the point at which the nerve to the stapedius muscle, *stp*, is given off, the symptoms will consist of paralysis of all the facial muscles, disturbances of hearing, and impairment of taste on the anterior third of the tongue. The velum palati is unaffected in this case, probably because its motor fibres are given off at the ganglion geniculatum, *Gg*. If the lesion is situated between the origin of the stapedius nerve and the point at which the chorda tympani, *cht*, leaves the facial nerve, the symptoms just mentioned will be present, with the exception of the disturbances of hearing. A lesion below the point at which the chorda tympani is given off will simply produce paralysis of the superficial muscles.

It must be remembered, however, that these remarks hold good only in those cases in which the lesion is of such character as entirely to destroy the conductibility of the nerve at the affected part.

Prognosis.—The prognosis depends chiefly on the character of the lesion which has given rise to the paralysis, and therefore varies according to that of the primary disease. When the nerve is involved directly, as in cases of rheumatic origin, or those due to infectious diseases, etc., the prognosis may be determined, in great measure, by the changes in electrical excitability.

When the excitability of the nerve and muscles is unchanged, the disease will usually recover spontaneously in from two to four weeks. If complete degeneration reaction is present, recovery cannot be looked for in less than from three to six or nine months. But the case should not be regarded as absolutely hopeless, even if the electrical excitability is abolished for a short period.

The development of muscular spasms and contracture is a very unfortunate event. In no case of this kind which has come under our observation has recovery occurred. The contracture usually continues to increase in severity, and after a while the muscles undergo a certain amount of atrophy. These two factors may give rise to considerable disfigurement of the face.

As a rule, the disease runs a longer course in those cases in which the lesion is situated within the Fallopian canal.

Treatment.—The causal treatment varies with the nature of the primary disease (affections of the middle ear, syphilitic lesions, tumors, etc.). The use of leeches, blisters, and the administration of strychnine, which are strenuously recommended by some writers, have been attended with such unsatisfactory results in our hands that we now rely exclusively upon electrical treatment.

In those cases in which the electrical excitability of the paralyzed nerve and muscles is unchanged, treatment is unnecessary, since recovery occurs spontaneously.

When complete degeneration reaction is present, electricity should be applied to both the nerve and the muscles, and in the case of the nerve the galvanic current alone should be employed. A small electrode, the anode, is placed immediately over the mastoid foramen (between the mastoid process and the lobe of the ear) on the affected side, the cathode (with a similar electrode) over the opposite mastoid foramen. The current will therefore pass through the petrous portion of the temporal bone, and act upon the nerve in its passage through the Fallopian canal. It should not be strong enough to produce a feeling of pain or vertigo, no interruptions should be made, and the sittings should be held for three or four minutes every other day. With this method we may combine labile galvanization of the muscles. One medium-sized electrode (usually the cathode) is placed upon the back of the neck, the other small electrode is slowly passed over the affected muscles. The frontalis and corrugator supercilii muscles are brought into play by passing the electrode horizontally across the forehead, a little above the eyebrow. The levator labii superioris alæque nasi, zygomatici, and buccinator are brought into play by passing the electrode along the side of the nose (beginning near the inner angle of the eye), and then outward across the cheek, immediately below the malar bone. Labile applications may also be made directly to the orbicularis oris and chin muscles. In applications to the orbicularis palpebrarum, we are in the habit of placing a very small electrode upon the muscle, at the outer angle of the eye, and then interrupting the current (by means of an interruptor in the handle of the electrode).

In an apparently incurable case of facial paralysis due to a gunshot wound, Faure and Furet stitched the peripheral extremity of the facial nerve to the adjacent branch of the spinal accessory. The results in this case were not very satisfactory, but in view of the experiments made by various observers it is probable that surgical interference will prove useful in a limited number of cases.

In some cases the excitability of the muscles will be found to have sunk to such a low ebb that it becomes necessary to employ the intrabuccal method of galvanization. One electrode is then placed upon the muscle which we desire to stimulate, the other directly opposite upon the mucous membrane of the cheek.

After the nerve has recovered its electrical excitability, the faradic current may be employed, either upon the muscles themselves, or by simply passing the electrode along a vertical line immediately in front of the ear, in order to stimulate the pes anserinus as it spreads out in this locality.

We may attempt to relieve contractures by stabile galvanization of the affected muscles, the negative pole being applied to the mastoid foramen, the positive pole to the contractured muscle. Massage of the muscles has also been employed for this purpose.

In all electrical applications in this disease, the electrodes should be very thoroughly moistened, and the current should merely possess sufficient strength to produce visible muscular contractions. *Leopold Putzel.*

FÆCES.—The term "fæces" is applied to the excrementitious substance that normally leaves the body through the anus. The material consists of the waste from the intestinal walls and the unabsorbed residues of the various secretions into the alimentary tract, together with an admixture, in varying amounts, of undigested and partially digested food, and at times such adventitious substances as may be taken into the alimentary canal *per os* and which are not absorbed. The common idea that the fæces in health consist chiefly of food residue is not sustained by the results of recent investigations.

After the intestinal contents have passed the ileo-cæcal valve, they rapidly take on the characteristic consistence, color, and odor of fæcal matter, being altered by the absorption of the liquids and soluble substances, as well as, to some extent, by the continuation of putrefactive and fermentative processes and by admixture with the strongly alkaline secretions of the large intestine. The extent of these changes is largely influenced by the rapidity with which the contents pass through the colon.

Physical Characters.—The *quantity* passed in twenty-four hours varies greatly, but is estimated to average 120–200 gm., in a healthy man on a mixed diet. It is dependent to some extent on the quantity and quality of food eaten, but is influenced as well by the condition of the digestive organs as regard secretion and absorption, and the frequency of evacuation. As a rule the quantity of fæces increases with the relative increase in the amount of vegetable food in the diet. It is probable that this is due largely to the greater resistance of vegetable food to digestive action and the subsequent stimulation of peristalsis by the undigested residues, with a resulting diminution of absorption. In an infant fed on cow's milk the quantity is regularly considerably greater, even up to ten times, than the amount passed by a breast-fed babe. This is due not alone to difference in digestibility, but to a considerable extent to the much larger quantity of milk given in artificial feeding, which both adds to the quantity of undigested food residue and increases the residue from intestinal secretion and waste. The quantity of fæces evacuated is occasionally increased by pathological products, including mucus, blood, pus, and serous fluid.

The *color* is normally derived from the intestinal secretions, notably from the bile, and under certain conditions is also very considerably influenced by the food, the stools of a mixed diet usually being a medium shade of brown, those of a meat diet dark to blackish-brown, and the evacuations following the exclusive ingestion of vegetable food being a light brown. The stools of an exclusive milk diet vary in color from orange to light yellow. The dark color is due to hæmatin, and to some extent to the compact, dry condition of the fæcal matter. In particular instances the color may be modified by special coloring matters ingested with the food, as, for example, chlorophyl, derived from large quantities of green vegetables. Adventitious ingesta as, *e.g.*, certain medicaments, may determine the color. Thus, calomel may cause a green coloration, probably by causing the presence of biliverdin, and bismuth or iron may each be reduced or may exceptionally appear as the black sulphide. Again, unusual changes in the intestinal contents may modify the color, as the growth of bacteria, producing pigment, notably green, or, as occurs frequently in infants, there may be a production of unusually strong alkalinity in the upper intestinal tract, causing the presence of biliverdin in the fæces in quantities sufficient to impart a green color. Finally, there are the clay stools after complete suppression of the bile and the similar appearance in cases without jaundice due to the presence of excessive amounts of fat.

The *odor* of the fæcal matter of adults is characteristic and is to be attributed to the presence of skatol and indol, and probably to other aromatic products formed by the putrefaction of the intestinal contents. When the passage through the intestines is rapid there may be little or no production of skatol, as in the rice-water stools of cholera, which are almost or quite odorless. The stools of an infant do not normally have a putrid odor, but if strongly acid they may have a rancid smell.

Normal stools are cylindrically *formed* and have a definite consistence. When the passage through the large intestines is rapid or the secretion into the bowels unusually abundant, they may become soft or even watery, while under opposite conditions they may be considerably hardened and assume the form of balls or very thin cylinders, these hardened masses being known as scybala. The so-called lead-pencil form is in no way indicative of intestinal stenosis, but is the rule when there has been complete abstinence from food, and may be caused by spastic or paralytic conditions of the large intestines.

After the exclusive ingestion of soft food the *structure* is usually homogeneous, while in fæces of the various mixed diets hard and undigested portions of food may be distinguished—as, for example, seeds, fragments of fruits and vegetables, or fibrous tissue. Adventitious admixtures of foreign substances are occasionally observed, such as fragments of wood, pieces of quill, buttons and pins. The appearance in the stools of bits of food tissue, recognizable to the naked eye, sometimes results from digestive insufficiency, either mechanical or chemical. Insufficient mastication is the most frequent mechanical fault. A failure of the chemical processes of gastric digestion is followed by the appearance of bits of connective tissue, while insufficient pancreatic digestion leads to the presence of undigested muscle fibre. Either biliary or pancreatic insufficiency may be followed by the appearance of much fat. Food fragments are more abundant in diarrhœal discharges, the material in some instances passing the entire length of the alimentary tract in a few hours and almost unchanged. In such stools pieces of meat may be seen or milk clots of various shapes and sizes. As a rule, the inner portion of formed stools is more recent than the outer, the passage through the intestines following the ordinary rule of flow, being more rapid in the centre and retarded at the periphery.

Fæcal matter has a certain *coherence.* If it does not contain evident food residue the mass usually does not crumble readily, when stirred with water, as do stools in which much food residue is present, particularly plant tissue and undigested casein. A large amount of fat increases the coherency, as does also in some instances much mucus, though possibly this is due to the accompanying fat.

Inspection of the alvine discharges occasionally reveals the presence of *pathological admixtures.* Blood, if from the lower bowel, is recognizable to the unaided eye, but, if changed by contact with the digestive juices, it merely imparts a dark color or tarry consistence to the stool. Likewise pus is recognizable only when it has been discharged into the lower part of the large intestine. The normal stool may contain on its surface visible mucus, but not in any considerable amounts. In catarrhal conditions of the intestines, however, the amount of mucus may be greatly increased, appearing either as a glassy layer surrounding the fæcal matter, as in diseased conditions of the lower portion of the bowel, or mixed with soft fæces, in which case the mucus adheres to a glass rod dipped into the evacuation; or, finally, it appears in watery dejecta as small floating particles, readily recognized. In membranous enteritis mucus is passed in long strings or as a continuous, tubular membrane, sometimes dense and opaque so as almost to appear fibrinous. In cholera and to a less extent in some other conditions great quantities of serous fluid, a true transudate, are evacuated with the intestinal contents.

MICROSCOPIC CHARACTERS.—Microscopic examination of fæcal matter reveals a mass of bacteria and detritus in which is embedded a greater or less number of recognizable morphological and crystalline elements, some being residue of food or adventitious ingesta, others being products from inhabitants of the intestinal tract, while still other such elements are those derived from the body itself and its secretions.

Vegetable cells and fibres of variable form may be encountered, some containing starch granules or masses of chlorophyl. Occasionally, especially in diarrhœal stools and where there is a failure of pancreatic digestion, starch granules more or less unaltered are recognized in considerable number. They turn blue in contact with a solution of iodine. Rosenheim states that he could not detect 0.6 per cent.; hence it appears that less than one-half per cent. of starch cannot be detected with certainty by microscopic examination.

Of the residues from *animal food,* connective tissue may be present in variable amount, being increased when this class of food is ingested in large quantity, and when there is a deficiency of gastric digestion. Where such food has been sparingly eaten, the appearance of areolar fibres in notable numbers is nearly always indicative of deficiency of the chemical processes of gastric digestion. Elastic fibres, except to a very limited extent in the instances in which they come from swallowed tuberculous sputa, are derived from the food and are not indicative of any condition of disease. Partially digested bile-stained muscle fibres are nearly always found in the stools, still preserving their transverse striæ so as to be recognizable, though the general appearance of the fibres may be much altered. They are not rendered more numerous by gastric deficiency, but they are apt to remain bound together by bands of undigested connective tissue. A large increase on a limited meat diet is indicative of deficiency of intestinal digestion. Undigested milk clot is at times present in the excrement of adults, and is frequently seen in the stools of infants. They are recognized by the absence of structure, the presence of fat globules and proteid, as indicated by microchemical tests, and the solubility of the coagulated proteid in dilute alkali and its reprecipitation by acetic acid.

Fat, in the form of globules and as fat tissues, is occasionally seen, but is commonly present as needles, single or in clusters. These are probably fatty acids in combination with calcium and magnesium, alkali-earth soaps. They are present in enormous numbers in acholic stools and are regularly increased when there is a deficiency in the absorption of fat.

Cholesterin *crystals* rarely appear in the stools, this substance not being a normal constituent of fæcal matter. Since it is usually present in meconium, in the stools of starvation, and in evacuations when digestion is arrested, its appearance in crystalline form is to be looked for in these conditions. Stercorin, into which cholesterin is normally converted in the intestinal tract, crystallizes in thin delicate needles and hence is distinguished with difficulty from alkali-earth soaps. Whether this substance appears in crystalline form in the stools is unknown.

Phosphate crystals are regularly seen in the microscopic examination of fæces, either as wedge-shaped prisms, single or in clusters, of the neutral calcium salt or as the triple phosphate in its various forms (see under *Urine*). They are without pathological significance.

Calcium oxalate crystals are frequently recognized in fæcal matter. They are in many instances derived from the food, but there is reason to believe that oxalate is at times formed in the fermentative and putrefactive processes of alimentation. In the light of our present knowledge its occurrence in crystalline form cannot be considered significant of any pathological process.

Crystals of other organic salts of calcium are described as occurring in stools, the lactate in the discharges of children, appearing as sheaves of radiating needles, and the acetate and butyrate in the discharges of gastric and intestinal catarrh. The occurrence of amorphous particles or dumbbell crystals of calcium carbonate and of prisms or dumbbell-shaped amorphous masses of calcium sulphate is exceedingly rare and probably devoid of pathological significance. After the administration of bismuth black crystals appear in the stools; in shape they closely resemble hæmin crystals.

Charcot-Leyden crystals are occasionally seen, most frequently when intestinal parasites, particularly worms, are present. They are also seen in typhoid fever and in catarrhal conditions of the bowel.

Of the *morphological elements* derived from the body epithelial cells are most frequently seen, as they are always present. Squamous epithelia come from the region of the anus, and are the least changed. The columnar variety is less frequently recognized, being much altered by partial digestion and abstraction of moisture. If in great numbers they point to intestinal catarrh, but are of no further diagnostic importance. The possibility of the presence of bits of neoplasm should always be borne in mind, but their recognition when such a growth exists is only occasionally possible. The casts of mucous enteritis and colitis frequently seem to be fibrinous, but microscopic examination shows that they consist of dense, more or less transformed mucus. Portions may be infiltrated with large numbers of small round cells. Blood, unless present in large amount, is recognized from the red corpuscles only when it comes from the lower portion of the rectum. Hemorrhagic stools frequently, however, contain reddish-brown hæmatoidin, sometimes presenting a somewhat crystalline structure, the crystals appearing in some instances after a hemorrhage had occurred several days before the stools were passed. In black tarry stools the presence of blood can be proved only by chemical tests (see Vol. II., page 74). Pus corpuscles occur in dysentery, ulcerative processes, and where an abscess has emptied into the bowel. Leucocytes are usually much degenerated and, if present in considerable numbers, are usually significant of ulceration.

Parasites.—Fæces contain lower forms of vegetable life which von Jaksch divides into two classes according to the manner in which they stain with iodo-potassic-iodide solution, viz., those that stain brown or brownish-yellow, and those that stain blue. The latter occur in relatively small numbers in health. Moulds are rarely present in fæcal matter, only the thrush fungus being occasionally seen, and then in children with thrush. Yeast cells are very common, being present even in the stools of breast-fed infants. They are more abundant in the acid stools of children. The fission fungi, chiefly bacteria, probably in most instances constitute the greater portion of the bulk of fæcal matter, occurring in enormous numbers, the figures obtained by different observers who have attempted to enumerate them ranging from 15,000 to 80,000 or even higher as an average for each milligram. Animals thrive in the absence of these forms of life in the intestinal contents, and they are not present during fœtal life, yet their presence is probably not without benefit. On a strict milk diet the number rapidly diminishes. In the stools of infants the bacteria commonly present are the Bacillus coli communis and the Bacillus lactis aerogenes; they give rise to acid fermentation with the production of acetic and higher fatty acids and occasionally formic acid, but they do not occasion a true putrefactive process. The varieties in the stools of adults are very numerous, more than fifty species having been identified, a number that does not at all adequately express the many species that probably are present under all possible conditions. It is generally accepted that the colon bacillus is the most constant inhabitant of the lower bowel, and with it are several of the different species active in putrefactive processes. For an account of the individual species and of the pathogenic bacteria, see the article on *Bacteria* and those that treat of the various diseases. Animal parasites of various description at times inhabit the intestinal tract, and may be passed with the stools. They include various protozoa, many species of worms, and not a few insects. For an account of these see the article on *Parasites.*

CHEMICAL COMPOSITION.—Normal fæces contain *moisture and volatile* substances to the extent of from sixty-eight to eighty-two per cent. of their weight, the water comprising about five per cent. of the total amount lost by the body through the various channels. In soft and watery stools the amount of water may increase to ninety-seven per cent. or more, while in hard stools it may diminish considerably. The other volatile constituents present in relatively small amounts are volatile fatty acids, phenol, indol, and skatol.

On ignition fæces usually yield an amount of *ash* equal to about one-eighth or less of the total solids, but this does not represent the condition of the mineral matter in the fresh material, since the acids of the ash are to a considerable extent formed from the organic matter in the process of combustion. Avoiding this error, Grundzach found in a normal adult, living on a mixed diet, that the bases were chiefly calcium and in smaller amounts potassium and magnesium, with still less of sodium and a very small amount of iron, and that twenty-two per cent. of these bases were combined with inorganic acids, chiefly phosphoric, but with small amounts of sulphuric and hydrochloric, and that the remaining seventy-eight per cent. were combined with organic and carbonic acids. In stools containing much serous transudate the quantity of chloride is greatly increased. Studying the secretions of the large intestine in a patient with an artificial anus in the lower ileum, Kobert and Koch found that on an average one-fourth of the solids is ash, about one-half of this in one examination being phosphate. It is evident, then, that the inorganic solids are derived from the intestinal and other secretions as well as from the food residue. The quantity of iron is usually found to vary between 2 and 25 mgm. in twenty-four hours, but it has been found to be 50 mgm. or more in malarial infection with much destruction of hæmoglobin.

The chief class of organic substances in the fæces is the *proteids,* the most important of these, the albuminoid bases of intestinal mucus, forming the chemical basis of fæcal matter. This is not mucin as was formerly supposed, but a phosphorus-containing, albuminous substance, probably identical with, or closely allied to, nucleo-albumin. True mucin is not regularly present in fæcal matter. It is, however, the chief substance imparting to human bile its mucilaginous character, and presumably may at times pass from the bile into the fæces, as well as from the saliva in which it is an important constituent, and from the food; but it has not been proved to be a regular constituent of human excrement. Appreciable quantities of albumins and globulins are present in pathological conditions only, namely, when there is serous fluid present, or when the food has passed through the body so rapidly as to escape complete digestion, and less frequently when the digestive function itself is not properly maintained. Thus in typhoid and dysentery albumins may be found; in the rice-water stools of cholera they are constantly present; they have likewise been found in stools deficient in bile. Since microscopic bits of bile-stained meat fibres can always be recognized in stools after a meat diet, it is presumable that myosin is present at the same time; but the quantity under ordinary conditions is hardly appreciable. Another class of proteids not present in the fæces of health is the products of digestion, the proteoses and peptones. They are constantly present whenever pus is found in the stools, and irregularly in certain other conditions. Nucleins are stated to be commonly present in fæcal matter. Whether in most instances they are true nucleins derived from the food or are paranucleins from mucus and nucleo-albumins of the food residue is uncertain, but it seems probable that in many instances they are paranucleins. Leucin and tyrosin are not present in the evacuations of health, and in diseases only when the passage through the lower bowel has been so rapid as not to permit of absorption. Hence they are to be looked for, and are frequently found in the stools of cholera and other conditions characterized by watery movements. Crystals of calcium and magnesium soaps were at one time believed to be tyrosin crystals, but their true nature is now recognized.

An important class of substances appearing in the fæces in greater or less quantity is the *fats* and their derivatives, consisting chiefly of neutral fat and soaps with some free fatty acids. The total quantity of these in an adult on an average mixed diet in health is only exceptionally as high as twenty-five per cent. of the dry solids of fæcal matter, the soaps and free fatty acids usually present making up three-quarters of the amount, with perhaps rather more soaps than free acids. The absolute quantity is influenced by the character of the food, only to a limited extent. In starvation and on some diets the fat of the excrement even exceeds the quantity ingested, while it has been observed that increasing the fats of the diet as much as twenty times only doubles the amount in the stools. When 100 gm. are ingested not more than from 4 to 6 per cent. of this amount should be contained in the fæces. It is interesting that the fat of lower melting-point is more readily absorbed, the fatty acids recovered from the stools usually melting seven degrees higher than those of the food. With diminished absorption the difference is less, and in diarrhœa may be almost inappreciable. The presence of free fatty acids in the ingested fats likewise favors absorption and correspondingly diminishes the amount excreted. In obstructive jaundice the total quantity of fat is greatly increased, the amount in some instances reaching seventy-five per cent. or more of the dry solids, without there being any considerable relative increase of neutral fat. With a failure of the pancreatic secretion, either with or without obstruction of the bile, there is likewise an increase in the fats excreted, but with a marked relative increase in the neutral fat. When the fats are thus increased, whether from insufficient bile or pancreatic fluid, the stools take the gray-white color and soft consistence that characterizes the so-called acholic stool. Mention should be made of the enormous, thick, pulpy stools of a dirty dark gray color and greasy appearance sometimes seen in diabetics. They contain a large quantity of neutral fat and other food residue, and are to be attributed to a diminution or absence of pancreatic fluid, from extensive lesion of the pancreas, which in these cases is the primary cause of the diabetic condition. Other conditions, in which an increase in the excretion of fats has been observed, are fevers, though usually not typhoid, and some cases of anæmia.

Carbohydrates appear in the fæces only when they are ingested and escape digestion and absorption. If they are easily soluble their utilization is usually complete, being determined entirely by the motor and absorptive functions, while starch demands the action of diastatic ferments for solution, and starch granules enclosed in cell walls are dependent still more on this latter function, and also call into exercise the action of bacteria to dissolve or decompose the cell cellulose. These facts are in accord with the observation that raw starch is more apt to appear in the stools than cooked and soluble carbohydrates. Considerably smaller quantities of starch can be detected by the fermentation test than by microscopic observation of the iodine reaction, by the former method 0.1 per cent. in one instance having been readily indicated, while by the latter 0.6 per cent. was not recognized, though it does not seem improbable that here the structural form was lost, and even that the starch was present in the soluble condition. Dextrin and gums may sometimes be detected in the stools, but even in diabetes dextrose is not present, though secretion into the intestines be induced by purgation. Of the pentoses rhamnose readily appears in the stools, xylose less readily, and arabinose only after its ingestion in large quantities. Cellulose is not dissolved by the digestive ferments, but to a slight extent is decomposed into methan and carbon dioxide by bacterial action. A large percentage is evacuated unchanged.

Of the *bile derivatives* the most important is the pigment. Under ordinary conditions bilirubin is reduced in the intestines to the color constantly present in fæces, known as hydrobilirubin, and to certain colorless closely allied substances capable of ready oxidation into pigment. The name "stercobilin," used by Vanlair and Masius, who supposed the color to be formed from bilirubin by oxidation, is still used by some writers rather than Maly's term, which expresses the true chemical relationship. The average amount contained in the twenty-four hours' evacuation was found by one observer to be 0.36 gm., not including the colorless products capable of yielding pigment by oxidation, of which a very considerable amount may be passed. Under certain conditions, as has been seen, the usual change in bile pigment does not occur, and biliverdin is present, giving to the discharge a green color. In the gray "acholic" stools, either bile pigment is absent or it is obscured by the presence of excessive quantities of fats. In the latter instances, the residue of fæces will be seen to be colored, when the fatty matter has been extracted with alcohol-ether. Biliary acids are to a large extent absorbed from the intestinal tract, either as such or after decomposition. Cholalic and choleidic acids are regularly present in the fæces, but not in large amount. Taurin is likewise present, but it has been found that the quantity in twenty-four hours is only 0.32 gm. When the passage through the intestines is very rapid, so as not to permit either the usual chemical changes or absorption, the bile acids or the products of their decomposition appear in the fæces in greater amount.

Lecithin is not present in more than traces, being either decomposed or absorbed as such; of the products of its decomposition the fatty acids are in part excreted with the fæces. It has been already stated under what conditions cholesterin is present and that ordinarily this substance is reduced, during its passage through the intestines, to stercorin. This discovery of Flint has received abundant confirmation in the last few years, and it is now established that normal fæces of the adult do not contain cholesterin. The amount of stercorin is usually one gram or less in twenty-four hours. This substance differs from cholesterin, not only in crystalline form but in chemical composition, its formula being $C_{27}H_{48}O$ (cholesterin $C_{27}H_{46}O$), and in chemical behavior. The chloroform solution gives with concentrated sulphuric acid a yellow coloration which on long standing changes to deep yellow and finally deep red. It does not form halogen addition products. The crystalline needles melt at 95–96° C. Little need be said of the fats and soaps of the bile, since they meet the same fate as these substances in food. That they appear in the fæces in part is indicated by the passage of fat in starvation, and also with a fat-free diet.

The volatile substances of fæces include volatile fatty acids and aromatic products of decomposition. Of the former three-fourths consist of acetic acid and the remainder of butyric, isobutyric, valerianic, and caproic acids, and perhaps traces of others higher in the fatty acid series. These bodies are formed very largely as a result of putrefying and fermenting of the intestinal contents. Lactic acid should be mentioned in this connection since it is regularly present in the acid stools of infants on a milk diet. The aromatic decomposition products phenol, indol, and skatol are present in the putrid fæces of the adult. Occasionally hydrogen sulphide, ammonia and other volatile bases contribute to the odor. In the milk stools of infants decomposition products are usually absent, though occasionally indol may be found. Indol and skatol are colorless crystalline solids formed in the large intestines from albuminous substance by putrefaction and possessing a disagreeable pungent odor. Indol has the formula $C_8H_6.NH$, while skatol is methyl indol, $C_8H_5CH_3.NH$. Each of these substances may be absorbed and is then eliminated in the urine or sweat, after undergoing slight oxidation and entering into ethereal combination either with acid potassium sulphate or with glycuronic acid, the indol in this condition appearing as indoxyl, the indican of the urine. In the fæces the quantity of these substances is small, but sufficient to give character to the excrement.

The *nitrogenous substances*, usually excreted by the kidneys, at times leave the body in the fæces in considerable amounts. Thus both urea and ammonium salts may be present in uræmia in notable quantities, while it appears that the purin bases, xanthin and hypoxanthin, are in leukæmia excreted through this channel to the extent of 1 gm. a day, which amount is even greater than leaves the body in the urine. Since these substances are present in small quantities in health, they must be considered normal constituents of the fæces. They are not increased in gout. Uric acid has not been found in the fæces of man

Mention should be made of the components of intestinal flatus. They consist of carbon dioxide, hydrogen, nitrogen, and methan. Ad. Schmidt concludes that the amount of nitrogen decreases with an increase in the tendency of the material to undergo fermentation, which condition depends on the amount and degree of digestion of the carbohydrate of the food. The quantity of methan varies in the same way.

There are present in the fæces substances that render this material poisonous. Regarding them and the poisonous products in the various diseases the reader is referred to the article on *Auto-intoxication*, and he is also reminded of the probability that the fæces will at times contain the toxins produced by the bacteria that are active in the intestines during the formation of the fæces.

An account of the chemistry of the fæces is incomplete without mention of the *chemical reaction*. In the adult it is alkaline, the acid contents of the upper intestinal tract being more than neutralized by the abundant secretion of sodium carbonate by the large intestine, and furnishing conditions favorable for ammoniacal fermentation. In typhoid, ammonium carbonate is present in unusual quantity, giving an increased alkalinity. After a diet rich in vegetables the fæces may be slightly acid; when bile is wanting they are strongly so. They are usually acid in infants, and in adults as well are markedly so in acute indigestion, the acidity being due to lactic and butyric acid fermentation.

Finally, mention should be made of certain *ferments* usually present in fæcal matter. A diastatic ferment is constantly present, derived apparently from the lower part of the small intestine, the amount varying inversely with the solids, being greatest in diarrhœa. It is not influenced by the character of the diet. Invertin is said to accompany diastase in the stools of infants. A proteolytic ferment, which is apparently trypsin that has escaped destruction in its rapid passage through the bowel, is reported to be present in diarrhœal discharges.

In the study of the digestibility or utilization of a definite food or dietary, it is important to distinguish the fæcal matter containing the residue from this particular ingested material. The *separation of the stools* thus becomes an important part of the experimental observation. This is accomplished by the ingestion, at the beginning and end of the experimental period, of material which so marks or characterizes the fæcal discharge as to render possible a mechanical separation, both from the fæcal matter preceding and from that immediately following. A considerable number of substances have been employed for this purpose, including in dogs bone, silica, and cork, and in man lampblack, milk, and carmin. Perhaps the most satisfactory procedure is to limit the meal immediately preceding the period of the special dietary, and also the meal immediately following, to milk, with which, at the same time, several gelatin capsules containing lampblack are to be taken. In the separation advantage can then be taken both of the salve-like consistence of milk stools and the dark color imparted by the lampblack. In many instances this separation is very satisfactory, but in diarrhœa, and particularly in constipation with formation of scybala, the boundary line is not always well marked.

After the fæces corresponding to a definite period have been obtained, it is then desirable to distinguish what portion of the material is residue from the ingested diet, and what is waste from the intestinal tract. The distinction between the *metabolism residue*, as these products are called, and the food residue is a matter of extreme difficulty, and although it has received much attention, there is no method known at the present day that serves to accomplish this end, except under definite and restricted conditions. The procedure of estimating the metabolic products in the fæces of starvation and deducting this amount from the total is inapplicable, since the metabolic products are increased with the ingestion of food and are dependent upon its character and amount. In many instances no effort is made to distinguish between metabolic and food residues, the total fæces being deducted from the amount of food ingested and the difference, instead of being termed "digestible" food, being called "available" or "utilized" food, and the factors deducted being termed "coefficient of availability" or "coefficient of utilization." Evidently these factors represent the net gain to the body rather than the digestibility of the food.

The fæces are at times the subject of special examination to ascertain the condition of the intestinal processes. The macroscopic appearance alone may indicate a diminution of the chemical or an increase in motor function, by showing an excess of fat or particles of food residue; but the microscopic appearances are of greater service to this end. When more exact knowledge is desired, the coefficients of availability of the nutrients of a given dietary of known amount and composition may be determined and these results compared with the coefficients in health. Ad. Schmidt and Strasburger have recently recommended different procedures that promise to be of some value in determining the utilization of carbohydrates. At the outset, after the ingestion of 0.3 gm. carmin, the patient is put on a special diet, known as No. 2, consisting daily of milk, 1,560 c.c., four eggs, 100 gm. zwieback, one plate barley soup (40 gm. barley), one plate flour soup (25 gm. flour), 375 c.c. bouillon, all containing 20 gm. sugar, in combination with the more common diet of 60 gm. chopped beef, and 250 gm. mashed potatoes (potatoes 190 gm., milk 60 gm., butter 7 gm.). In diet No. 1 the chopped beef and mashed potatoes are omitted. No. 3 consists of 1,690 c.c. milk, 2 eggs, flour soup, bouillon, and mashed potatoes as in diet No. 2, sugar 10 gm., milk rolls 225 gm., meat (cutlet) 150 gm. The diets are seen to contain carbohydrate in increasing amounts from 1 to 3 and successively in more difficultly utilizable form, as well. For most cases either or both 1 and 3 will be found advantageous in addition to 2. After the disappearance of the carmin, usually after an interval of three or four days, during which the diet is continued, the fæces are submitted to a fermentation test, as follows: The fresh stools are mixed with water (usually two parts) to the consistence of a thick fluid, and the mixture is put in a fermentation tube of about 30 c.c. capacity and left at body temperature. The formation of gas in twenty-four hours to one-third the capacity of the tube is a weak reaction; to two-thirds moderate, and more than this strong. Five conditions determine the development of the reaction, namely, the presence of (1) starch, (2) nutritive material, (3) obligatory bacteria, (4) a diastatic ferment, and (5) the absence of a high grade of acidity. A late appearance of gas is due to putrefaction of the material, and is not to be given the same consideration as the early fermentation. Strasburger concludes that early fermentation with diet 1 is always pathological; with diet 2, is on the boundary, but is more frequently pathological; with diet 3, is normal, yet in the majority of normal stools does not appear. Only positive results are of diagnostic value. Under most conditions carbohydrate is the variable factor, and it is apparent that Schmidt's method is primarily directed to the estimation of the utilization of this class of nutrients. The same investigator has devised a method of measuring the bulk of undigested meat fibre in the fæces after the ingestion of these same dietaries. The method consists essentially in determining the reduction in volume which the residue in the fæces undergoes when submitted to the action of pepsin-hydrochloric acid. The value of the procedure remains to be determined.

Ernest Ellsworth Smith.

FAHRENHEIT AND CENTIGRADE SCALES.—The following table, showing the value in degrees, tenths of a degree, and hundredths of a degree, according to the Fahrenheit scale, of every tenth of a degree of temperature from 44° to 32° Centigrade, while perhaps belonging more properly in the article entitled *Thermometer*, is introduced in this place for the reason that such early introduction is likely to prove a convenience to many readers of the Handbook. In the determination of the limits of this short table only the needs of the clinician have been considered.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
44.0	111.20	0.9	0.82	0.9	0.62
.9	111.02	.8	.64	.8	.44
.8	.84	.7	.46	.7	.26
.7	.66	.6	.28	.6	96.08
.6	.48	.5	103.10	.5	.90
.5	.30	.4	.92	.4	.72
.4	110.12	.3	.74	.3	.54
.3	.94	.2	.56	.2	.36
.2	.76	.1	.38	.1	.18
.1	.58	39.0	.20	35.0	95.00
43.0	.40	.9	102.02	.9	.82
.9	.22	.8	.84	.8	.64
.8	109.04	.7	.66	.7	.46
.7	.86	.6	.48	.6	.28
.6	.68	.5	.30	.5	94.10
.5	.50	.4	101.12	.4	.92
.4	.32	.3	.94	.3	.74
.3	108.14	.2	.76	.2	.56
.2	.96	.1	.58	.1	.38
.1	.78	38.0	.40	34.0	.20
42.0	.60	.9	.22	.9	93.02
.9	.42	.8	100.04	.8	.84
.8	.24	.7	.86	.7	.66
.7	107.06	.6	.68	.6	.48
.6	.88	.5	.50	.5	.30
.5	.70	.4	.32	.4	92.12
.4	.52	.3	99.14	.3	.94
.3	.34	.2	.96	.2	.76
.2	106.16	.1	.78	.1	.58
.1	.98	37.0	.60	33.0	.40
41.0	.80	.9	.42	.9	.22
.9	.62	.8	.24	.8	91.04
.8	.44	.7	98.06	.7	.86
.7	.26	.6	.88	.6	.68
.6	105.08	.5	.70	.5	.50
.5	.90	.4	.52	.4	.32
.4	.72	.3	.34	.3	90.14
.3	.54	.2	97.16	.2	.96
.2	.36	.1	.98	.1	.78
.1	.18	36.0	.80	32.0	89.60
40.0	104.00				

FAINTING. See *Brain, Anæmia of*, and *Syncope.*

FALKENSTEIN, GERMANY.—There is nothing remarkable about the climate of Falkenstein which would warrant any extended account of it as a health resort. The name "Falkenstein," however, has become famous in connection with the renowned sanatorium situated there, and this demands notice as being one of the best exponents of the sanatorium treatment of pulmonary tuberculosis in the world.

Nine miles out of Frankfort is the picturesque village of Cronberg in the Taunus Hills, where resided the late Dowager Empress of Germany for a good part of the year. A walk of about forty minutes up the hill from here brings one to the tiny village of Falkenstein, commanding an extended view over the valley of the Main with Frankfort in the distance. Here, in a location protected on the north, west, and east is situated the sanatorium, 1,300 feet above sea-level. The institution consists of a main building with two wings joining it at an obtuse angle and enclosing a large terrace, and two annexes united to the main building by covered promenade galleries. The terrace enclosed by the wings of the main building and looking toward the south, has a continuous broad veranda of glass, provided with sun blinds and curtains, where upon cushioned reclining chairs one sees long rows of patients lying rolled in rugs, taking the rest cure, some reading or writing, others conversing, and a few sleeping. There are also, near by, pavilions, some revolving, affording further opportunity for the same treatment. The climate is that of central Germany, its principal characteristic being a pure atmosphere free from dust, which, from Dettweiler's point of view, is the chief consideration in the climatic treatment of phthisis, provided it can be utilized continuously. Only about half the days in the month are sunny.

The internal arrangements are similar to those in the other large sanatoria: A large, well-ventilated dining-hall accommodating two hundred persons; reading, music, and billiard rooms; post and telegraph office; bacteriological and analytical laboratory; throat and douche rooms; various offices and consulting rooms. Each sleeping-room has a special ventilating flue and the usual simple furnishings; linoleum floors, washable walls; they are never swept but cleaned with damp or wet cloths. The windows are always open. Near by are the dairy and stable, gas-works, and a disinfecting apparatus. As in most of the other sanatoria the system of drainage is on the principle of chemical precipitation with cleansing basin. The large corridors for rest treatment (*Liegehallen*), which were first introduced as a means of treatment at Falkenstein, have a powerful gaslight between the heads of every two chairs, permitting the patients to read as they lie out in the evening. Blue-glass spittoons containing water are distributed in the halls on brackets, smaller ones in the rooms, and white crockery ware ones on the grounds. Each patient is required to carry with him the Dettweiler pocket spit-cup, and expectoration except in these receptacles is absolutely prohibited—handkerchiefs or cloths not being allowed. The compliance with this law seemed to be perfect. The sputum is disposed of by throwing it into the waste water or by burning.

The *jour médical* for an average patient, as told by one of them, is as follows:

7 A.M. Rubbing—dry or wet—or a douche.

8. Breakfast, consisting of coffee, tea, or chocolate, with rolls, butter, honey, and milk.

Until 10, the rest treatment in the reclining chairs.

10. Second breakfast, of bread, butter, milk and soup, with wine or cognac. (Upon this latter Dr. Dettweiler places a high value.)

10:30 to 1 P.M. The rest treatment again.

1. Dinner: soup, fish, vegetables, several kinds of meat, fruit, dessert, and coffee.

2 to 4:30. The rest cure again.

4. Milk.

4:30 to 7:30. Rest or walking.

7:30. Supper, consisting of soup, hot and cold meats, salads, preserves.

After supper the rest treatment until 10, with milk at 9.

10. Retire.

It will be seen from the above that the rest treatment in the open air (*Ruheluft-Kur*) occupies most of the day, and herein is a marked difference between Görbersdorf and Falkenstein. Dettweiler lays great stress upon *rest* in the open air, while Brehmer puts the emphasis upon methodical *hill-climbing.* Dettweiler so insists upon this system of open-air rest treatment that the most of his patients spend from seven to eleven hours daily in the open air in spite of rain, fog, or snow, and of cold, even to 12° below zero. As Ransom observes: "This form of treatment is almost independent of weather." Each patient on admission is carefully studied, not only his physical condition, but his temperament and will power, and his intelligent and willing co-operation with the physician is obtained. His plan of life is then arranged in all its details. He is constantly under the eye of the physicians, and always sees them at the principal meals. To this skilled watchfulness and care, the hygienic-dietetic measures, and the hyperaëration is due the success attained in such an institution. Here, as at the other sanatoria, the treatment of fever is continued rest, physically and mentally, and this applies to all patients who have a temperature of 37.5° to 38° C.

(99.5° to 100.4° F.) or over. At some sanatoria, as at Hohenhonnef, the patient is not even allowed to lie out in the *Liegehallen*, for fear the moving and excitement may keep up or increase his fever, but is kept absolutely quiet in his room. Generally this treatment alone, with some Hungarian wine or cognac, suffices in a short time to reduce the temperature to normal. Knopf explains this disappearance of fever after a short sojourn at a sanatorium by the almost total absence of pathogenic microbes, especially the streptococci, in the pure atmosphere.

I was struck with the appearance of the patients as I saw them at dinner; they hardly differed from the persons one would see in the dining-room of an ordinary hotel, and presented only to a slight degree, if at all, the appearance one usually associates with a consumptive. During the entire meal I hardly heard a cough. Moreover, it was as contented and happy-looking an assemblage as one would see anywhere. The average length of residence is about three months.

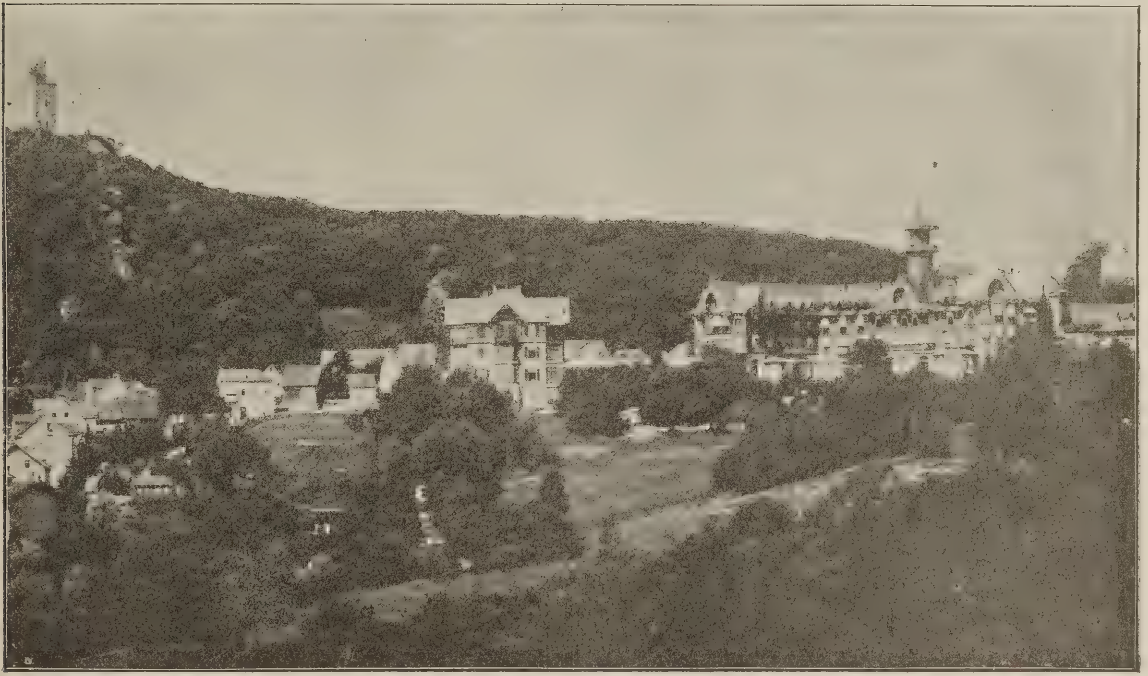

FIG. 2080.—The Sanatorium at Falkenstein, as seen from Adolfsfelsen.

The results at Falkenstein, from 1876 to 1886, of the patients who have been kept under observation since their discharge, is 13.2 per cent. of complete cures, and 11 per cent. of relative cures (disease arrested), a total of 24.2 per cent.; 60 per cent. or more are improved. The expense here, as at most of the other sanatoria, is from $20 to $25 a week.

One cannot leave Falkenstein without carrying away a lasting impression of its founder and guiding genius, Dr. Dettweiler. It was my good fortune to ride up to the sanatorium with him from his modest home in Cronberg. It was a chilly, disagreeable morning in May, much like our March weather, which perhaps suggested his remark that it was not so much a climate as a method; tuberculosis could be cured in any climate. He told me of his early struggle with tuberculosis in his own case, when it seemed that he could not live. But the struggle was successful, and now he is a man of middle age or more, and has accomplished an immense amount of work, and is still the inspiration of his sanatorium. He is a man of great simplicity and sympathy, inspiring enthusiasm, and well illustrates the power of the personal factor in the success of the physician. He makes his patients love him, and in consequence they readily yield to his will and guidance. "In him," as Dr. Thorne says, "reason, science, and long experience are correlated into action by discrimination, adaptability, sympathy, and unbending will. In both of the senses in which the term can be employed, he is a presiding genius."

Edward O. Otis.

FALLOPIAN TUBE. (ANATOMICAL.)—See *Generative Organs, Female.*

FALLOPIAN TUBES, DISEASES OF.—ANATOMY.—In order to comprehend completely the nature of the diseases and neoplasms of the Fallopian tubes or oviducts, a thorough knowledge of their anatomy and embryology is requisite. The oviduct has a common origin with the vagina and uterus from the Müllerian ducts. The upper portion of these ducts remains open externally and that portion forms the pavilion of the tube. The occurrence of secondary pavilions, or ostia, may be explained by supposing that the canal of Müller is not completely closed in all its extent at that period of embryonic life when the two borders of the gutter which give origin to it are turned toward each other to transform the channel into a tube. The Müllerian ducts unite lower in their course to form the uterus and vagina, and the limit of this union is the insertion of the round ligament. The similarity in structure and the continuity of mucous membrane explain how readily disease of vagina and uterus extends to and involves the tubes. These structures are veritably the excretory ducts of the ovaries and are placed, one on each side of the uterus, to permit the passage of the spermatozoid toward the ovary and to transmit the ovule from that organ to the uterus. They are in the upper folds of the broad ligaments, and their average length is from 10 to 12 cm. Their length may be unequal and is subject to considerable variation, as in cases of ovarian tumors, when it may be very much increased. The tube consists of three coats, the incomplete peritoneal, the longitudinal and circular muscular, and the mucous. It is divided into the isthmus, the ampulla, and the fimbriated extremity. The uterine extremity, or isthmus, is its narrowest portion and will barely admit a bristle. The ostium abdominale is surrounded by a number of fimbriæ which are formed by the outward bulging of the mucous membrane. These fimbriæ are lined upon the inner surface by mucous membrane and externally by the peritoneum, so that there is a direct continuity of mucous and serous membranes at this point. No distinct glands, such as are found in the cervix and uterus, have been observed in the tubes. The mucous crypts formed by the folds of the mucous membrane are probably glandular in character and secrete an albuminous fluid. This membrane has a single layer of ciliated columnar epithelium upon two or three layers of supporting cells which are round or pyriform. The cells abruptly terminate at the ends of the fimbriæ, where the margin between the columnar and pavement epithelium is distinctly marked.

Malformations.—Malformations of the Fallopian tubes are rare. One tube may be longer than the other. Sometimes the lumen of the tube is increased. The abnormality which is most likely to attract attention is the presence of one or more accessory abdominal ostia. They are usually situated near the abdominal end of the tube, in the upper part of its wall, and are surrounded by fimbriæ. Ferraresi found six openings upon one tube, all of which were surrounded by fimbriæ. These openings are probably due to failure in closure of the groove in the germinal epithelium, or to splitting of the Müllerian duct after it has closed. There may also be accessory tubes, either as cystic diverticula starting from the tube, or as independent tubes with fimbriæ starting from the mesosalpinx. The tubes may be absent on one or both sides, which absence is due to a destruction of the corresponding part of the Müllerian ducts in the embryo. Very often a small pedunculated cyst, about the size of a hazelnut, is found attached to the fimbriæ or to the outer aspect of the tube. These cysts are called hydatids, or cysts of Morgagni. They are said to occur in eight per cent. of adults, and are not of surgical interest.

Diseases of the Fallopian Tubes.—The diseases of the Fallopian tubes may be either *inflammatory* or *neoplastic*. The inflammatory changes produced in the Fallopian tubes are variously classified according to the extent of involvement. Salpingitis is the ordinary term applied to inflammation of the oviducts. Perisalpingitis is inflammation of the peritoneal covering of the tube, a condition which occurs only as a part of a more extended pelvic peritonitis. Endosalpingitis is the term applied to inflammation of the mucous lining of the tube. Hydrosalpinx indicates an accumulation of serous fluid within the structure. If it is distended with blood, it is termed hæmatosalpinx; or, when a purulent collection is present, the term pyosalpinx is applicable. Hydrops tubæ profluens is the term applied to an accumulation of fluid in a tube in which the uterine end remains permeable, and, as the fluid increases, permits the excess to be drained through the uterine canal. The open tube acts as a safety valve, preventing the overdistention of the oviduct which occasionally completely collapses after evacuation. Tuberculosis will be discussed under infections of the tube, and the neoplasms affecting the tube will be considered later.

Etiology.—A knowledge of the causation of salpingitis is requisite for its prophylaxis and treatment. According to Noeggerath gonorrhœal infection is the most usual cause of inflammation of the tubes. Polk believes that puerperal endometritis is the most *frequent* cause of salpingitis, while the most *destructive* form is that produced by gonorrhœal infection. Salpingitis is hardly ever a primary disease, being as a rule secondary to inflammation of the uterus or peritoneum. The inflammation may follow the mucous membrane by a direct extension, or be propagated from the uterus through the lymphatics of the broad ligament. It may be due to infectious and exanthematous disease. Malposition of the uterus, neoplasms affecting the uterus, or stenosis of the uterine os with retention of secretion in its cavity, may produce tubal inflammation. Exposure to cold, too frequent coition, or violent exercise immediately before menstruation are causative factors. Puerperal infection following labor or abortion under septic conditions may be placed among the chief causes of inflammation of the appendages. Unfortunately, in many cases unwise surgical interference, intra-uterine exploration, the introduction of the sound, and the employment of stem pessaries, are to be classified among the sources of tubal infection. Too often the gynecologist is called upon to perform sacrificial operations upon the adnexa to relieve the patient from the results of gynecological tinkering. The practice of some physicians, now fortunately nearly obsolete, of making intra-uterine application of caustics or astringents with routine introduction of the sound, is responsible for endometritis and a secondary salpingitis. There is a direct relationship between the diseases of the endometrium and tubal affection. Salpingitis cannot be considered an uncomplicated entity; it is invariably associated with more or less metritis or ovaritis, and there is the constant danger of the process involving the pelvic peritoneum. The various micro-organisms that have been identified in tubal affections are the gonococcus, the staphylococcus, streptococcus, and Bacillus tuberculosis. In a few cases the presence of the Bacterium coli commune has been demonstrated. Frommel and Witte have found the pneumococus in puerperal salpingitis. One of the saddest things to contemplate is the possibility of the innocent, newly married woman being infected with the gonococci, and yet this is observed over and over again and emphasizes the necessity for complete cure of men contemplating marriage. The ravages of gonorrhœal infection and the dire results produced upon the appendages demand plain speech and earnest teaching upon this point. Another cause of these diseases is the neglect of proper attention being paid to the pubescent girl. Engelmann in a tabulation of 5,000 cases among school girls found that 66 per cent. were afflicted with more or less menstrual suffering; and no doubt a large proportion of these cases presented more or less symptoms of tubal congestion.

Pathology.—Many classifications have been presented of the various forms of tubal disease; but here simplicity is the secret of lucidity. Like inflammations of other structures, salpingitis may be either acute or chronic and it may affect one or both tubes. As it becomes chronic, or the infection increases in severity, the various changes noted occur, such as the formation of hydro-, hæmato-, or pyosalpinx.

Acute Salpingitis.—In the first stages of acute salpingitis the disease is confined to the mucous membrane of the tube, whence it quickly extends to the muscular and peritoneal coats. The whole tube is soft, congested, and friable. In early salpingitis a prominent feature is small-celled infiltration of the plicæ which causes them to become thick and club-shaped. Blood-vessels, at first dilated, soon appear narrower than in health. The folds become œdematous and hyperæmic. The epithelial cells are swollen, show slight increase in the size of their nuclei, and vacuoles form in their protoplasm. The secretion is increased and contains mucus, albuminoids, and epithelial débris. This secretion exudes from the abdominal ostium when the tube is squeezed. When the infected material escapes into the peritoneal cavity, the danger of pelvic peritonitis is great. The direct channel established by the tubes between the uterine and peritoneal cavities facilitates peritoneal infection. But the frequency of this is diminished by nature's provision in producing occlusion of the abdominal ostia of the tubes, which closes these orifices. Many cases of acute salpingitis undergo resolution and the tubes are restored to their normal condition. This is particularly true of the milder forms of catarrhal salpingitis.

In *chronic salpingitis* there is an extension of the inflammation and the formation of adhesions with more definite changes in the tubal structure. Many cases are either subacute or chronic from the beginning; that is, they never present violent or acute symptoms. The lesions produced are numerous. The tube may become enlarged and more tortuous than normal, its muscular coat more extensively involved, producing interstitial salpingitis. As it progresses, the cilia of the lining cells disappear, the wall of the tube becomes thicker and harder, with an increased amount of connective tissue. The conservative closure of the abdominal ostium is of much importance, because it prevents leakage of the septic material through this channel and consequently diminishes the danger of peritonitis. When the inflammation extends from the tubal mucous membrane to the peritoneal covering, the fimbriæ retract and become invaginated in the tube; and this opening, instead of being surrounded with protruding, divergent fimbriæ, becomes rounded and smaller. The process continues until the edges finally meet and unite by peritoneal adhesions, causing complete closure of the opening. As the tube increases in size and weight its position is frequently changed and it becomes adherent to the uterus, ovaries, or the pelvic peritoneum. Usually there is obstruction of the uterine extremity of the tube, which is produced by swelling of the mucous membrane in the narrow isthmus, by cicatricial contraction, or by a sharp flexure along the course of the tortuous tube. The greatest distention is at the outer extremity of the tube so that it assumes a pear shape. If the tube be brought into connection with the ovary, either by agglutination of the fimbrial extremity to the surface of that organ or by burrowing between the layers of the broad ligament, the tissue intervening between the cavity of the tube and the cyst of the ovary may be absorbed or perforated, and the two cavities thrown into one, forming a tubo-ovarian cyst; or, if infection has occurred, a tubo-ovarian abscess.

Hydrosalpinx.—The fluid of a hydrosalpinx may be colorless, slightly yellow, or brownish when colored by the presence of blood. As the accumulation increases, the walls of the cyst atrophy and become very thin; the epithelium and the mucous membrane in time disappear until nothing but a thin-walled sac remains. The size of the tube varies from that of the finger to that of a fœtal head. In a case reported by the writer, the hydrosalpinx was the size of a cocoanut and was mistaken for an ovarian cyst. As a rule the fluid from a hydrosalpinx is sterile, unirritating to the peritoneum, and readily absorbed.

Hæmatosalpinx.—True hæmatosalpinx rarely occurs. Extra-uterine pregnancy is the most common cause of an accumulation of blood in the Fallopian tube and should not be termed hæmatosalpinx. [The subject of ectopic gestation is treated elsewhere.] Hæmatosalpinx may occur, however, when hemorrhage takes place into a tube previously closed by inflammatory action. Such an accident may result from traumatism or by the torsion of the pedicle of a tubal cyst, or when there is an obstruction to egress of menstrual fluid. The writer has never seen a case of tubal hemorrhage in which ectopic gestation could be excluded. Although the positive evidence of impregnation may not be present, yet undoubtedly the vast majority of these cases are of such origin.

Pyosalpinx, or a collection of pus in the closed Fallopian tube,[1] produces a gradual thinning of its wall. This thinning predisposes to rupture and the escape of the pus into the peritoneal cavity. The pyosalpinx often becomes adherent to the posterior wall of the uterus, to the rectum, or to the small intestine. The contents of the sac are usually at first clear, non-odorous pus; but proximity to the bowel frequently causes this to assume a more offensive character. The possibility of a pyosalpinx being evacuated through the uterus has been asserted by some authorities. This, however, is a very unusual occurrence, and it is probable that in such cases the escaped fluid has been retained uterine secretion. The pus of a pyosalpinx varies greatly in character. In the early stages of the disease it is actively septic; but later the micro-organisms become inert, die, and disappear. According to Penrose, out of 133 cases of acute and chronic suppuration of the uterine appendages in which the pus was examined bacteriologically, no organisms whatever were found in 82 cases; in other words, the pus was sterile in about 61 per cent. of the cases. Out of 116 cases Wertheim found that in 72 there were no bacteria at all; in 32 there were gonococci; in 6 there were streptococci, and in 1 staphylococci. It is only when the pus is in contact with an absorbing surface, or escapes into the peritoneal cavity, that general inflammation or septic symptoms develop. It is surprising what a quantity of pus may exist in cases in which there has been no deviation of the pulse or temperature from the normal. In this connection it is well to call attention to the frequent coexistence of appendiceal and adnexal disease. Adhesions will be found between the appendix and the tube and ovary in about fifteen per cent. of all cases of tubal disease. The proximity of the appendix to the right appendage and the frequent coexistence of inflammation in both are often perplexing to the diagnostician.

Symptoms.—In acute salpingitis the patient usually complains of pelvic pain and tenderness which is most marked in the ovarian regions. The temperature is elevated, the pulse rapid, and the knees are often drawn up as in peritonitis. There are no pathognomonic symptoms. A chill may occur. Bimanual examination reveals marked tenderness upon pressure in the vaginal fornices, and there is a sense of fulness in the region of the tubes. If the pelvic peritoneum and cellular tissues are involved, the whole vaginal vault will feel resistant. If the patient is thin and the abdominal walls are sufficiently relaxed, the enlarged, tender tube may be palpated by the conjoined method. When the disease becomes chronic, with more extensive pathological changes, the symptoms vary and may in part be attributed to associated ovarian disease. Pain is generally continuous, but may be relieved by the recumbent posture. It is increased by exercise, coition, and during defecation. It may be felt in one or both ovarian regions or in the sacral region. It often has a colicky character due to the contractions of the inflamed muscular coat. It may be dull and aching, or at times sharp and lancinating, and is very much worse at each menstrual period. The dysmenorrhœa in salpingitis is usually characteristic, beginning several days before the flow and lasting throughout the whole of the period. While the disease is quiescent there may be no acceleration of the pulse or increase of the temperature. The patient frequently has marked exacerbation of the pain and sometimes acute attacks, with symptoms of local peritonitis. Her life is in constant jeopardy, as there is the ever-present possibility of intraperitoneal rupture, with escape of septic material and consequent peritonitis. Leucorrhœa is common, more or less constant, and may vary from a slight, thin watery to a profuse, purulent, or sanguinolent discharge. Menorrhagia or metrorrhagia is frequently present. The general health suffers, the patient loses flesh and strength, and marked nervous and reflex symptoms develop. Sterility is the rule in these cases, as the disease of the mucous membrane and destruction of the ciliated epithelium render the passage of the ovum into the uterus difficult. A careful study of the history of the patient will aid in diagnosis; but our chief reliance must be upon our bimanual examination. If the diagnosis is obscure and the patient's abdominal walls are rigid, it is wise to employ an anæsthetic. For this purpose the bromide of ethyl is convenient. The small amount of anæsthetic required, the rapidity of its influence, and the quick return to consciousness make this anæsthetic of distinct value where a brief period of anæsthesia is desired. By bimanual examination the tube may be felt lying beside the uterus or behind it in Douglas' pouch. The shape of the tube and its connection with the uterus may be traced, and it will appear tender, thickened, and often distorted. Fluctuation may not be elicited even when there is a large amount of fluid, if the sac is much thickened. If the inflammation has been extensive and the disease is bilateral, the tubes, ovaries, and uterus may form one conglomerate mass filling the true pelvis. Usually the uterus is pushed forward in the pelvis and the appendages occupy the recto-uterine space. Frequently the appendage primarily diseased becomes prolapsed first, and the other appendage rests upon it and may be felt by the abdominal examining hand. Recto-abdominal examination should also be practised. Disease of the tubes may be mistaken for cellulitis, oöphoritis, or pelvic hæmatocele. An adherent, retrodisplaced uterus must also be differentiated. In women with very thick abdominal walls physical examination is unsatisfactory, but the history of the case and the symptomatology usually justify the diagnosis.

TREATMENT.—The treatment of tubal disease is *prophylactic, palliative,* and *surgical.* In order to prevent disease of the tubes attention must be paid to the woman's health from puberty to the menopause. At puberty the young girl should be carefully advised by her parents or physician in regard to the menstrual function. The false modesty which keeps her in ignorance of her sexual physiology is responsible for untold suffering. During menstruation she should avoid exposure or violent exercise and should evacuate the bladder whenever the desire is present. Proper clothing should be worn at all times; and corsets, if worn at all, should support rather than compress the viscera; but they should be positively interdicted until complete development has occurred, since it is reprehensible to compress the waist of a growing girl by anything tight or constricting. In married women tubal trouble may be prevented by the rules of health already mentioned, by careful attention after abortion or labor, by repair of all lacerations of the cervix or perineum which do not heal immediately after labor. If gonorrhœa develops, energetic treatment will often prevent the disease extending from the vagina and uterus to the appendages. Whenever there is metritis or endometritis, palliative measures should be used. Careful antisepsis in the treatment of abortion or during the puerperium will diminish the frequency of salpingitis. As gonorrhœa and sepsis are two great causes of inflammation in these organs, our attention should be devoted to their prevention. In all necessary intra-uterine exploration there should be the same rigid asepsis as though the peritoneal cavity were to be invaded; for the tube is a direct channel of communication between the uterus and that important serous membrane, the peritoneum.

Palliative Treatment.—When a patient is suffering from *acute salpingitis* in its early stages, the treatment should be expectant: 1. Absolute rest in the recumbent position. 2. The administration of saline purgatives: from one to two drachms of Rochelle salts every two hours until the bowels have moved freely; or four to six ounces of liquor magnesiæ citratis may be given in the same manner. It is far better to keep the bowels open by such drugs as these than to keep the patient under the influence of opiates. Hot vaginal douches of some antiseptic solution such as corrosive sublimate, creolin, or lysol, of a temperature of from 100° to 110° F., and not less than one gallon in quantity, should be employed two or three times a day. Much relief will be afforded by the use of ice-bags over the lower abdomen. In fact the cold applications are preferable to hot fomentations, as the cold relieves the pain and has a tendency to prevent the extension of inflammation. If there is elevation of temperature, with a rapid, high-tensioned pulse, tincture of aconite in small doses is indicated. If there is a tendency to abdominal distention, high enemata of sulphate of magnesia, glycerin and water, or of the milk of asafœtida, will favor peristalsis and the expulsion of gas. All examinations should be made with great care and gentleness and no oftener than is essential to determine the progress of the disease. The patient should be carefully watched, and if the temperature and pulse rate decrease and the tenderness is subsiding, the palliative treatment should be continued; but if the symptoms are increasing in severity and the possibility of peritonitis or abscess formation is at hand, operation is demanded for the purpose of removing the source of infection. In some cases of acute salpingitis with virulent infection fatal peritonitis will result in three or four days after the onset of the attack. On the other hand, in a great number of these cases the closure of the abdominal ostium of the tube prevents extension to the peritoneum; but the tube itself is badly damaged by the disease and remains in a condition of chronic catarrhal or purulent salpingitis.

The treatment of *chronic salpingitis* varies somewhat from that of the acute. It must be borne in mind that tubal disease is almost invariably associated with metritis and oöphoritis, and that these must be considered if effective treatment is to be given. The patient's condition and the degree of suffering experienced are to be our guides in deciding whether we shall employ palliative treatment or surgical interference. Curative measures should be directed to any accompanying endometritis. If this is chronic, aseptic curetting is the proper remedy; but it must be used with great caution, as intra-uterine manipulations are apt to produce an acute attack of the tubal trouble. For chronic salpingitis hot, germicidal solutions should be daily employed; and vaginal tampons of sterilized lamb's wool saturated with fifty-per-cent solution of boroglyceride in glycerin, or a fifteen-per-cent. solution of ichthyol in glycerin, should be inserted two or three times a week. The tampon improves the pelvic condition by raising the uterus to a higher level and maintaining it there. The tampon may be left in position twenty-four hours; and, after its removal, a copious vaginal douche of the antiseptic solution should be used twice daily, with the patient in a recumbent position. The same attention should be paid to the bowels, diet, etc., as in acute salpingitis. Rest at the menstrual period, the avoidance of exposure to cold, and abstinence from coition will aid in relieving the symptoms. Internally, preparations of viburnum, hydrastis, or ergot may be given. In some cases of chronic salpingitis beneficial results have been derived from the use of pelvic massage as advocated by Thure Brandt. It produces a rapid alteration in the inflammatory accumulations, setting free the uterus and its adjacent organs. It may be employed in subacute or chronic inflammation unassociated with pus formation. American physicians, however, have not secured the same brilliant results by massage as have been reported by European gynecologists. The writer has found that patients were unwilling to undergo the discomfort of the prolonged séances of pelvic massage necessary to secure definite results.

Surgical Treatment.—When palliative methods have failed and the woman experiences suffering constantly, or at the menstrual periods, and is unwilling longer to lead the life of an invalid; then it is necessary to consider surgical interference. When there are gross tubal lesions such as hydro-, hæmato-, or pyosalpinx, or retrodisplacements of the uterus with adherent tubes and ovaries, nothing but operation will afford permanent relief. One of two routes may be selected according to the individual preference of the surgeon. These are the vaginal and the abdominal; but no fast rule can be laid down as to which route should be preferred, as the choice depends upon the condition of the patient, the environment in which the operation must be performed, and the skill of the surgeon. Often both routes will be employed in the same operation, as in the evacuation and irrigation of a tubal abscess per vaginam prior to its removal by abdominal section. If the patient is very weak, the pulse rapid, and the abscess bulging into the vagina, a vaginal cœliotomy may be rapidly performed, the pus evacuated, and drainage introduced without anæsthesia or with a very brief period of it. In a great many cases of vaginal section the patient will so far recover her health as to obviate the necessity for abdominal cœliotomy. The technique of the vaginal operation is as follows: After complete evacuation of the bowels and the necessary anæsthesia, the vagina should be thoroughly scrubbed with a solution of creolin or lysol, ʒ i.; tincture of green soap, ℥ i.; hot water, O.i.; after which it should be irrigated with sterilized water and alcohol. A curvilinear incision is then made through the posterior vaginal wall and the finger, or a pair of scissors, is carefully pushed into the tubal mass. The pus or blood is evacuated, the cavity being constantly irrigated with hot normal salt solution. Care should be taken that all accumulations be evacuated and that no injury be done to the viscera. After the cavity has been perfectly cleansed, it should be packed with iodoform gauze, which by its pressure controls any slight oozing that may occur and serves as a vaginal drain. If the vagina is capacious and the adhesions are not too firm, salpingo-oöphorectomy, if indicated, may be done through this incision. The gauze packing is allowed to remain for three or four days, and after its removal vaginal douches of normal salt solution, or of a 1 to 2,000 formalin solution, should be given. The advantages of the vaginal route are the absence of abdominal incision, less shock, less danger of hernia, and more rapid convalescence. There is, however, always the possibility of a secondary operation being required.

The operations which may be done by the abdominal route are: salpingotomy, salpingostomy, and salpingectomy. In all of these the same general preparation is to be observed as in other abdominal operations. *Salpingotomy,* or resection of the Fallopian tube, is the result of conservative evolution; and it has been proved that, after the resection of a diseased portion of the tube, regeneration may take place and the tube continue to functionate. Dudley, of New York, has reported some splendid operative results and has resected the tubes even when gonorrhœal pyosalpinx was present. The success in these conservative operations depends upon the careful selection of cases and the skill of the individual surgeon.

Salpingostomy is the establishment of a new opening in the Fallopian tube when the normal one has been closed by some inflammatory process, and is particularly indicated when it is desirable to retain the child-bearing function. The new opening in the tube may be sutured directly over the ovary so that when the Graafian follicle ruptures the ovule may pass directly into the tube. In all conservative surgery upon the tubes care must be taken thoroughly to cleanse that canal and to protect the peritoneal cavity from its contents.

Salpingectomy.—In nearly all cases requiring removal of the tubes, the ovary demands extirpation also. Salpingectomy is required when the symptoms are marked and the tube is irreparably diseased. There must be danger to life or serious impairment of health before this operation is resorted to. The exact nature and the extent of the operation depend upon the disease for which it is performed, the age and social condition of the patient, and the ability of the operator. In performing salpingectomy the abdomen is aseptically prepared, and an incision, from two to three inches in length, is made in the median line, midway between the umbilicus and the pubes. An examination is made to ascertain the position, extent, and strength of adhesions. When the pelvic viscera are found in one conglomerate mass, it is well first to find the fundus of the uterus and then proceed to the tubal enucleation. The intestines and general peritoneal cavity should be walled off by gauze pads. The use of the Trendelenburg position is of great advantage, as it permits the operator to see as well as feel the visceral adhesions. In old cases in which the adhesions are firm and organized, great care must be taken to prevent visceral injury. If the tubal sac in a pyosalpinx ruptures during removal, gauze pads should be at hand to catch the escaping fluid and the cavity should be irrigated with a large quantity of normal salt solution. After the appendages have been freed, chromicized catgut ligatures should be applied to the pedicle in small sections rather than *en masse.* A supporting button should be left beyond the ligature to prevent its slipping and the possibility of secondary hemorrhage. If the interstitial portion of the tube is involved, it is often wise to remove the fundus of the uterus also. Frequently there will be denuded peritoneal surfaces which require suturing to control oozing. A careful examination should be made to find whether the rectum, sigmoid flexure, or small intestine has been injured. Drainage is not so often employed as formerly, as it has been shown by Clark that by thorough irrigation and postural drainage the use of tubes or gauze is unnecessary. If there is an extensive raw oozing surface or fear of infection, then the pelvic cavity may be packed with iodoform gauze, one end of which is carried through a posterior vaginal incision into that canal. The great advantages in such vaginal drainage are that drainage takes place from the most dependent portion of the pelvis and there is no danger of a ventral hernia or abdominal fistula along the drainage tract. After the appendages have been removed and a most vigilant examination has been made to see that all bleeding is controlled and all injuries are repaired, the abdominal incision should be closed and the patient treated according to the usual methods employed in abdominal surgery. These, however, cannot be discussed here for lack of space.

Tuberculosis is more apt to affect the tubes than any other part of the genital apparatus. They are involved in nearly all cases of genital tuberculosis, which is much more common than was formerly supposed. According to Penrose and Beyea, it is present in eighteen per cent. of cases subjected to the operation of salpingo-oöphorectomy; while Williams found that in one out of every twelve operations for the removal of the tubes and ovaries that were the seat of inflammatory disease, this infection was present. It may be either primary or secondary, but is usually the latter. The infection may take place through the blood from the peritoneum or the uterus. Coition with men affected with genito-urinary tuberculosis may be an occasional cause. This disease may involve the tube long before puberty. Chaffey has described a case in which a child aged four died with tuberculosis in the lungs and abdominal organs, and the tubal walls presented caseous nodular masses. Silcock has detected a similar condition in a child aged five.

Tuberculosis of the tube may be divided into three classes: *miliary, chronic diffuse,* and *chronic fibroid* (Penrose). Miliary tuberculosis of the tube may be a part of a general condition, or it may belong primarily to the tube, when micro-examination shows giant epithelioid cell tubercles scattered through the mucous membrane. This is the first stage and the process may progress no further or may be converted into one of the other varieties. In the chronic diffuse tuberculosis the mucous membrane is infiltrated with epithelioid cells, miliary tubercles, and areas of caseation. The tube may be filled with cheesy material or with pus, and in time the mucous membrane becomes entirely destroyed. In the chronic fibroid variety, there is a great increase of connective tissue between the tubercles, the lumen of the tube is distorted, and a few miliary tubercles are found scattered through the mucous membrane. This form advances very slowly and not infrequently terminates in a spontaneous cure. The symptoms of tubal tuberculosis resemble those of salpingitis and are not at all characteristic. The diagnosis is often obscure, but occasionally it may be made by careful bimanual examination, by an inquiry into the question of hereditary predisposition, and by finding other signs of it, especially in the lungs. Most cases of tubal tuberculosis have been discovered unexpectedly at the time of operation or autopsy. The treatment is prophylactic, hygienic or medical, and surgical. If the condition of the patient permits, salpingo-oöphorectomy should be performed; and if there is any evidence of disease of the uterus it should be removed at the same time. The presence of tuberculous peritonitis indicates rather than contraindicates operation. The curative action of cœliotomy in these cases is probably due to a combination of the peritoneal traumatism during the operation, thermic influence, penetration of air into the abdominal cavity, and the action of light. Therefore such operation offers to the patient the best chance of cure.

Neoplasms of the oviducts are exceedingly rare except as the result of inflammatory changes. *Cysts* varying in size from a pea to a walnut are found in all the walls of the tube but most frequently beneath the peritoneum. Sänger divides these cysts into three classes: 1. Serous cysts, which arise from the accumulation of serous fluid between the lamellæ of the mucous membrane. 2. Lymphangiectatic cysts. 3. The hydatid of Morgagni, which is a physiological cyst at the end of the tubal fimbriæ. *Myoma.*—Notwithstanding the fact that fibroid tumors of the uterus are of such common occurrence, myoma of the tube is very rare. Bland Sutton reports a case in which an interstitial myoma, the size of a Tangerine orange, was found in the walls of the tube at the juncture of the uterine and middle thirds. Most of the reported myomata of the tube are pedunculated and of the subperitoneal class. In Sir J. Y. Simpson's case the tumor was "of a size equal to that of a child's head"; but usually the growths are so small as to create no disturbance. Many observers have mistaken a collection of tuberculous matter and inflammatory changes in chronic salpingitis for minute fibroids. *Cancer.*—Carcinoma of the tube may be either primary or secondary, though the latter is more frequent and results from involvement of the tube in cancer of the uterus or ovaries. The disease is generally confined to one tube. Until recently it was asserted in text books that the secondary was the only variety, but at least seventeen authentic cases of primary carcinoma of the tube have been described. The cancer in nearly every case assumed a villous or papillomatous appearance. *Sarcoma* has also been noted. Montgomery refers to a case reported by Kahlden in which the tube formed a sausage-shaped mass filled with soft, cauliflower-like material. Under the microscope it showed various degenerations such as round-cell and spindle-cell sarcoma and a papillomatous structure wanting in connective tissue. *Lipomata*, or fatty tumors, from the size of a bean to that of a walnut, have been found in connection with the tubes. Parona reports a case in which the lipoma weighed a little under three ounces and measured three and a half inches in the longest diameter; traces of the wall of the tube with characteristic ciliated epithelium were seen through the adipose tissue of the lipoma. *Deciduoma malignum.*—Two cases of this remarkable disease have been described, both in Sänger's opinion quite authentic; and if we can have the malignant degeneration of a portion of the placenta or chorion within the uterus, it is not surprising that a similar malignant change may occur in the tubal sac of ectopic pregnancy. Sänger claims that this is an additional argument, not only for active interference in cases of extra-uterine pregnancy, but also for the extirpation of the appendages in which tubal abortion has occurred. *Papillomata.*—According to Doran papilloma is the term applied to an exuberant morbid growth which lies in the interior of the Fallopian tube. Sutton, however, classifies such tumors as adenomata. Doran considers that these tubal papillomata are allied to the condylomata and warts seen on the external genitals irritated by venereal discharges. These ordinarily are innocent but may undergo malignant degeneration. Sänger divides them into two forms: simple cystic and hydropic. *Dermoids.*—According to Doran there is no sound evidence that a dermoid tumor of the tube has ever been seen. *Enchondromata* are small, semitransparent, cartilaginous masses, occasionally situated on the ends of the fimbriæ (Montgomery).

The *general treatment* for all these tubal neoplasms is salpingectomy. They are rarely differentiated, as subjective symptoms throw no light upon the diagnosis and examination reveals merely a tubal mass without any determination of its character. *Wilmer Krusen.*

FARCY. See *Glanders.*

FARMVILLE LITHIA SPRINGS.—Prince Edward County, Virginia.

Post-Office.—Farmville. Boarding-houses.

Access.—Viâ Norfolk and Western Railroad to Farmville, thence one-half mile to springs. Farmville is a thriving town of 4,000 inhabitants, located 55 miles east of Lynchburg and 72 miles south of Richmond. The railroad depot is within convenient walking distance of the springs, but carriages are at hand for all those who prefer to ride. There are many features of interest in this historic region. The springs are beautifully situated about 550 feet above the sea-level. The surrounding country is very pleasing to the eye, and on every hand the visitor is met by names and locations of familiar memory. Not far from the springs are found the battlefields of Chancellorsville, Appomattox, Rapidan, Five Forks, and others of lesser note. The climate here is bracing, the temperature ranging from 40° to 50° F. in winter and from 80° to 90° F. in summer. The springs are eight or ten in number, and yield about fifty gallons of water per hour. The following analysis is by Prof. E. T. Fristoe, of the Columbian University, Washington:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	5.30
Sodium sulphate	3.59
Potassium sulphate	.18
Calcium sulphate	1.81
Lithium bicarbonate	3.76
Calcium bicarbonate	1.33
Magnesium carbonate	2.71
Ferrous carbonate	1.26
Manganous carbonate	Trace.
Alumina	2.52
Silica	3.92
Iodine	Trace.
Sulphuric acid	Trace.
Organic matter	Small quantity.
Total	26.38

Carbonic acid gas, 74.20 cubic inches.

It will be observed that this water contains a fair proportion of the bicarbonate of lithium. It is also abundantly charged with carbonic acid gas, and contains sufficient sulphate of sodium to give it a mild laxative action. The water has come into wide use as a corrective of the uric-acid diathesis, and is sold in all parts of the country. Its best effects have been observed in gout, renal and vesical calculus, Bright's disease, and dyspepsia. The iron in the water gives it also excellent properties as a ferruginous tonic. *James K. Crook.*

FAT NECROSIS. See *Pancreas, Diseases of.*

FATTY DEGENERATION; FATTY INFILTRATION. See *Lipogenesis.*

FAUQUIER WHITE SULPHUR SPRINGS.—Fauquier County, Virginia.

Post-Office.—Fauquier White Sulphur Springs. Hotel.

Access.—From Washington viâ Virginia Midland Railroad to Warrenton, 56 miles southward, thence a drive of six miles to the springs. The visitor to this favored locality is pleasantly impressed during the forty minutes' ride from the picturesque town of Warrenton to the springs. The drive is over a fairly graded road through a country where the well-stocked farms and handsome residences are indicative of an advanced degree of thrift and refinement. The springs are charmingly situated among the foothills of the Blue Ridge at an elevation of 1,000 feet above the sea-level. The surrounding grounds comprise an area of 400 acres in a high state of cultivation and abounding in shaded walks and drives through hills and valleys. Being sheltered on the west by wooded hills, the location admits of invalids enjoying the open air with safety almost daily throughout the year. The clear waters of the Rappahannock River border the western boundary of the park and sweep along the base of the mountains, where the huntsman or the disciple of Izaak Walton will find an ample reward for his tramp among the hills or his patience by the waterside. The waters of these springs have been well known for upward of seventy-five years. As early as 1834 a company was formed of well-known men from Maryland and Virginia, and two large hotels and a number of cottages capable of accommodating 1,000 persons were built. So attractive were the resort and its surroundings that the Legislature of Virginia held a summer session there in 1849. At the beginning of the war the place was in the full blast of prosperity. In August, 1862, it was the scene of a fierce fight between the Federal and Confederate forces, and the two hotels were burned. In 1877 a company was formed for the purpose of restoring the famous old resort to public uses. The present accommodations consist of an elaborate and commodious fire-proof hotel fitted with all modern improvements. There are besides a number of cottages, capable of accommodating 500 guests; they are located in a fine grove of elms convenient to the main hotel.

The following analysis of the spring water was made in 1878 by Prof. Thomas Antisell, of Washington, D. C.:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Calcium bicarbonate	7.88
Magnesium bicarbonate	2.47
Sodium chloride	3.75
Calcium sulphate	3.39
Iron phosphate Iron sulphate	2.14
Sodium and potassium sulphate	1.63
Calcium and magnesium phosphate	.64
Gaseous matter, etc	.10
Total	22.00
Gases.	**Cu. in.**
Carbonic acid	11.00
Sulphureted hydrogen	Small quantity.

Temperature of water at springs, 55° F.

The source of the mineral ingredients of the springs lies in the country rock, which is an aluminum slate, the beds of which lie nearly horizontal, or with a slight slope, and hold between their layers sandy, ferruginous seams, in which are embedded crystals of iron pyrites with some hydrated oxide of manganese. The water is properly classed as a sulphureted alkaline-chalybeate, possessing alterative, tonic, and diuretic properties. It has long been recommended in the various forms of dyspepsia, in intestinal disorders and in liver complaints. Its diuretic properties are utilized in dropsical affections due to renal and cardiac diseases, as well as in the early stages of Bright's disease. In the condition known as neurasthenia, produced by overwork, anxiety, or other causes, a course of this water has been found to be markedly advantageous. In certain female complaints, notably in menstrual disorders due to anæmia, its action is prompt and permanent. *James K. Crook.*

FAVUS. See *Tinea.*

FEBRICULA (diminutive of *Febris*, fever).—(Synonyms: Simple fever, Simple continued fever.)

Febricula is a convenient term which finds its justification in ignorance rather than in knowledge.

A pyretic state lasting from one (*ephemera*) to ten days, in which the temperature probably does not rise above 102° F. except temporarily, nor the pulse usually above 100 to 120, accompanied by a white, furred tongue, constipation, loss of appetite, by headache which may be sharp; but without other derangement of the bowels than constipation, without any exanthem, without any distinguishable internal or external local lesion, inflammatory or otherwise; ending in sudden resolution and rapid, easy recovery—this is febricula, and we agree to call this general condition, whatever may be the cause, by that name for want of a better, and because it requires some designation.

Febricula has no pathology, because it always ends in recovery. Febricula ending in death takes on another name. Abortive typhoid, typhus, or relapsing fever; scarlet fever or measles without their rash; tonsillitis with an inappreciable tonsillar affection; acute rheumatism or erysipelas without localization, may all conceal themselves under the term febricula.

On the other hand, the same symptoms—as shown in a mild or short continued fever—may result from exposure to extremes of temperature, from exhaustion, from digestive disturbances, from derangement of the nervous centres.

The *febris ardens* of the tropics, various degrees of which are encountered in the United States during the occasonal hot "waves" of our summer months, belongs more appropriately under insolation, or heat- or sun-fever.

The DIAGNOSIS of febricula can be reached only by exclusion, and should only be made subject to ready revision.

The TREATMENT is simple and consists of a saline laxative, diuretics, diaphoretics, or refrigerants, as indicated in the particular case. *George B. Shattuck.*

FEEDING, FORCIBLE.—Forcible feeding means the introduction of food into the organism against (or without) the will of the individual. It is employed in two groups of cases: (1) In patients exhibiting a comatose or semi-comatose condition for a considerable period of time; and (2) in patients afflicted with brain troubles (insanity, melancholia), when they refuse nourishment.

The insane form the largest contingent of cases in which forcible feeding must be resorted to. Here it is the most important measure not only to prolong life but also often for the establishment of a cure, whenever this is possible.

In some instances small quantities of liquid or semi-liquid food are introduced into the mouth of the patient and the latter is told to swallow. In case this procedure is effective, enough nourishment may be slowly ingested in this way. But if this means fails, as it often does, or in patients who are not accessible to our exhortations, the principal measure of forcible feeding consists in the artificial ingestion of nourishment. The latter is performed in three ways: (1) Gastric alimentation by means of a tube inserted into this organ; (2) rectal alimentation; (3) subcutaneous alimentation.

By far the most frequently employed and the most efficient method of forcible feeding consists in the first measure. It seems that the stomach pump was used for this purpose long before its application in gastric affections as a therapeutic measure (Kussmaul, 1867); for in 1857 William Hamilton[1] mentions the stomach pump as a well-known procedure in the feeding of the insane. The same writer had also introduced a new means of gastric alimentation by inserting a tube through the nostril into the œsophagus and providing it with a funnel. This method is still used nowadays, and I may, therefore, be allowed to cite Hamilton in full. He says:

"Acting upon a method advised, in cases of trismus, of introducing into the nostrils a tube to the posterior fauces, through which nourishment may be passed to a point beyond voluntary muscular control, an instrument was constructed which was efficaciously employed on the 24th of June last. It consists of an elastic tube, twenty-four inches long, the size of a catheter, at the open end of which a funnel is attached. Near its end the tube is slightly curved. The curve is maintained by the introduction of a silver wire, two inches in length, one end being bent upon itself to preserve it in position, to prevent its impinging at right angles upon the posterior wall of the pharynx during the first stage of the process, and, during the second, keeps the tube from interfering with the glottis. The tube being adjusted, the operator pours through it nutritious or medicated liquids, which are immediately, by automatic action, conveyed into the stomach. This operation is not disturbed, owing to the length and flexibility of the tube, by any considerable motion of the patient's head."

Forcible gastric alimentation is performed in the following manner: A soft-rubber tube (regular stomach tube), provided with a connecting glass-piece at the outside end, is introduced, either by way of the mouth (when this is possible, or after keeping the mouth open by a gag) or by way of the nostril, into the stomach. A rubber tube with funnel attachment is next slipped over the glass-piece, and the apparatus is then ready for the reception of food. The latter, in liquid or semi-liquid form, is poured from a pitcher into the funnel, which at first must be somewhat lowered, in order to prevent the entrance of too much air into the stomach, and then afterward raised to about the level of the patient's face, until the whole quantity desired has been ingested. Then the entire apparatus is quickly removed after compressing the tube with the fingers in such a manner that no contents may escape from it while in the pharynx. It will be readily understood that assistance is oftentimes required during this procedure, especially when we are dealing with maniacal patients. The arms and feet of such a patient must sometimes be kept quiet by strong assistants.

The amount and kind of foods to be introduced into the stomach can be varied. The principle is, to introduce liquid and semi-liquid food in sufficient quantity for the maintenance of life. As a rule a combination of milk and eggs beaten up together is the most important and most frequently used form of nourishment. F. Jolly[2] recommends using one quart and a half of milk and three raw eggs for each feeding, twice daily. The milk can also be combined with cream, with somatose, or with plasmon, or indeed with any of the beef juices in use. A tablespoonful or two of sugar and some table salt may also be conveniently added. In the same manner meat powder, purée of brain, peas, etc., can be mixed with water or milk and introduced into the stomach.

Inasmuch as forcible gastric feeding permits us to utilize a great variety of foods, and especially a considerable quantity of them, it lies within our power not only to keep the patient in balance, but also sometimes to make him gain in flesh. Forcible gastric feeding is therefore the means par excellence for forcible feeding. The other two methods mentioned above—rectal alimentation and subcutaneous feeding—play here but an unimportant part. Rectal alimentation may be for a time combined with gastric alimentation when it is very difficult, on account of the patient's struggles, to introduce the tube into the stomach. Subcutaneous alimentation is still less important, as the amount of nutritive value introduced in this way hardly amounts to anything. William H. Murray[3] recommends subcutaneous injections of olive oil (10–20 c.c.) twice daily. *Max Einhorn.*

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[1] William Hamilton: On Forced Alimentation. Journal of Insanity, January, 1857, p. 278.

[2] F. Jolly: Ernährungstherapie bei Nervenkrankheiten. E. von Leyden's Handbuch der Ernährungstherapie, Bd. ii., p. 168, 1898.

[3] William H. Murray: Buck's Reference Handbook of the Medical Sciences, 1886, vol. iii., p. 53.

FEES, LEGAL RULES GOVERNING THE COLLECTION OF.—As far back as history goes we find mention of physicians; physicians' fees are probably nearly as ancient, but the privilege of being able to recover these fees in a court of law is, in countries other than our own, of quite recent date. In the United States the law has never made any distinction between the professional man who works with his brain and the laborer who works with his hands. *Honoraria*, with their interesting history and subtle legal evasions, are unknown here; and the rules governing the collection or recovery of physicians' fees are, in the main, the same as would be enforced in any other vocation. But still, there are a few peculiarities arising from the nature of the services rendered, or from the circumstances that attend the need of these services; also there exist in many minds certain superstitions or fallacies with regard to a physician's services and remuneration. Hence a few general rules on these topics may be of value. At the outset it must be premised that only a very general sketch can be given; on points of detail the various States differ considerably among themselves, and even in the same State diverse decisions have been rendered on a single point. This article is intended to be for physicians what an article of similar length in a "Family Medicine Book" might be for lawyers, *viz.*, a guide till proper professional advice can be obtained. A physician ought to know enough law to avoid being his own lawyer.

A physician's right to receive compensation for his services is based upon a contract either express or implied, and this same contract will form a basis for an action to recover that compensation in a court of law. If there is an express agreement between the parties (1) as to the amount or rate of compensation, and (2) as to the person or persons to be considered responsible for the same, then no difficulty is likely to arise. But this is seldom the case, and as a rule an *implied* contract will be inferred as existing between the physician and either the patient or some one representing the patient. In this implied contract the *physician* will be expected to treat his patient with reasonable skill, judgment, and experience, according to the standard prevailing in the locality in which he practises, he will pay such visits as he may deem necessary; and the *patient*, by his acceptance of these services, undertakes to obey the physician's instructions and to pay a reasonable remuneration. What constitutes a reasonable remuneration will depend upon the usual rate of charges for similar services in the neighborhood. Here it may be remarked that failure to cure will be no bar to the physician's recovering his fee. The physician as a rule does not guarantee a cure; but should he undertake a case on the distinct understanding that "no cure no pay" shall hold, he will be required to abide by it. A patient will not be allowed to allege that he got no benefit from the physician's treatment provided the physician uses reasonable care, skill, etc.; but it has been held that where the treatment was such that it could under no circumstances effect any possible benefit, the patient might allege this as a reason for non-payment. If the services were intended to be gratuitous, and the physician so declared, no action will lie for recovery; but if the physician intended his services to be free, and did not at the time declare such intention, an action for recovery will lie; and in any case the law will presume the existence of liability on the patient's part, and it will be for him to prove that such services were intended to be without charge. But an implied contract can exist not only with the patient, but in some cases with a person or persons who stand in such relation to the patient as to be legally liable for necessaries furnished. Thus, in medical services rendered to a child under age, the parent is held by the implied contract to pay; so, too, is the husband for services rendered to his wife, and the guardian for services rendered to his ward. It is very necessary that the proper person be held responsible, and the physician will do well to ascertain the individual to whom he should present his account. Thus, where a married daughter was taken ill in her father's house, and received a physician's services, the father acquiescing, the father was not liable, but the husband, and it was held that even if the father had sent for the physician it would have made no difference. With regard to parent and child under age, it may be said that as a rule the father is liable, even if the child is away from home, provided he is absent with his father's consent, but not if the child has run away or left without the father's approval. If the father is dead, the mother is liable only so far as the child has a separate estate, and if the child has no separate estate she is not liable. In the case of husband and wife the husband is liable; and if the wife be divorced, the husband will still be liable unless the physician is made acquainted with the fact. So, too, where the husband declines to be responsible for debts incurred by his wife, it is incumbent on him to furnish this information to the physician, or else the courts will uphold the physician in recovering his fee from the husband.

"There are two cases in which, in the absence of an express contract, the physician may recover if either husband or wife has property. The first is the case in which a physician renders services to a woman not knowing her to be married. Here the husband is liable as an undisclosed principal, but the wife is also liable as an agent who has made a contract without disclosing the fact of agency, and either could be sued notwithstanding a previous judgment against the other for the same cause, if it has not been satisfied." "The second is the case in which a married woman, who has been abandoned by her husband, or is living apart from him for good cause, renders him liable for necessaries furnished to herself and her children. Here the debt is that of the husband, and the wife may not be sued directly. But a judgment against the husband may be enforced against the wife's separate property, by an action instituted for that purpose" (Willard A. Mitchell, in *Medical Record*, 1894, vol. xlv., p. 98).

In the case of a third party other than the parent, husband, or guardian, what are the liabilities of such third parties for the payment of the physician's fees? When a physician depends on the promise, express or implied, of a third party, it is necessary to understand whether that third party promises as for himself or as a guarantor. In the former case he is liable, and the physician can recover from him. In the latter case it is necessary that such promise should be in writing. The Statute of Frauds declares that "no action shall be brought . . . whereby to charge the defendant upon any special promise to answer for the debt, default, or miscarriage of another person . . . unless the agreement upon which such action shall be brought, or some memorandum or note thereof, shall be in writing, and signed by the party to be charged therewith, or some other person thereunto by him lawfully authorized." To take a few illustrative cases: (1) A asks a physician to attend X, and says, "I will pay," or "I will see you paid"; A is liable, and the physician can recover from him. (2) A asks a physician to attend X, and says, "If X does not pay you, I will"; unless this is in writing the physician cannot recover from A. (3) A says to a physician, *after* services have been rendered to X, "I will pay"; A is not liable. In Case 1 above, there is an ordinary contract, and the transaction does not come under the Statute of Frauds because it is an independent promise. Case 2 is covered by the Statute of Frauds. In Case 3 there is no consideration upon which to found a contract, and therefore, whether oral or written, such a promise has no legal value. But, in the large majority of cases, although third parties are ready enough to call a physician for a friend or neighbor, they are singularly reticent on the subject of remuneration. If the third party avers that he is merely an agent, he has no responsibility; but where he does not state that he is acting as an agent the courts differ as to the question of liability. This subject of agency has been condensed as follows: "It is a general principle of the law of agency that one who procures services to be done for another is not himself chargeable as the debtor, unless he omits to make known his principal, or erroneously supposes that he has authority, or exceeds his authority, or expressly or implicitly engages to be answerable either by directly promising to pay for them if rendered, or by doing or saying something which justifies the person who is to perform them in supposing that the one who applies to him engages to pay for them" (Judge Daly, in Buck *vs.* Amidon). In dealing with corporations, such as railway companies, the physician will do well to remember that unless he has an *express* contract with the corporation, an *implied* contract is with the person who receives his services. Thus, in a railway accident, a conductor asks a physician to attend X; the company is not liable. Doubtless there is in every corporation some officer whose acts will bind the corporation; if such an officer requests professional services for an injured person, the company will be held responsible, but not otherwise; and it will be for the physician to prove that the officer who employed him had such authority, or else that the company subsequently ratified the action of an inferior officer. The question of the liability of corporations, with the various decisions, is far too large to enter upon here.

Having now seen how, in most cases, a contract is made, let us note the points necessary to success in invoking the aid of the law. In the first place—with regard to his own legal status—the physician must have fulfilled all the legal requirements of the State in which he practises, and of the county or counties in which he has an office. He must be legally qualified to practise. If there is any omission or flaw in this respect he cannot recover his fees in any State, with the possible exception of Missouri. And as with professional services so, too, with medicines supplied. Generally the physician will be presumed to have fulfilled all legal requirements, and the burden of proving that there is any irregularity will rest upon the defendant. The legally qualified physician can also recover for services rendered by students working under his direction, and also for a physician employed to assist him, even when this assistant is not legally qualified. But it would seem that a physician, being unable to attend a case, and sending in his place another physician not his assistant, cannot recover for that other physician. The patient is also liable for the expenses of a consultant, even when there is no express stipulation. Next, the physician will have to prove that he has rendered the services for which the charges are made. This is a difficult and delicate matter, and the physician must proceed cautiously, for the question of "professional secrecy" presents itself. In the States of Arizona, Arkansas, California, Colorado, Idaho, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Utah, Washington, Wisconsin, and Wyoming a duly qualified physician is positively restrained from disclosing anything that the patient has confided to him professionally. In States not mentioned above, the physician may be allowed to testify in detail as to the services that he has rendered. In case the physician should be unlicensed the patient has no such protection, and a full account of the services may be given. Great diversity exists as to the interpretation of these rules, and chiefly as to what is included in the term "privileged communication." In the next place the account sent in will be scrutinized. The court will hardly recognize an account as vague as the "To professional services" so commonly rendered. While there is some difference in the requirements of the various States, the safest course is to present an account in which each item is specifically given under its proper date, and with its own charge against it. "The general rule that one who receives a bill or account, and retains it without objection, will be deemed to have acquiesced in its correctness, does not apply to a bill rendered for personal services without previous agreement as to rate of compensation. But where a part payment is made on such bill without protest, it becomes an account stated, which may be sued upon without giving evidence as to the value of the services rendered; and the bill need not have been an itemized one" (Willard A. Mitchell, in *Medical Record*, 1894, vol. xlv., p. 98). With regard to the value of the services rendered—in case this is disputed (and the defendant is likely to dispute everything)—the custom of other physicians in the locality, and the plaintiff's own custom in other cases may be cited; but it will be proper for the defendant to urge that the physician had on previous occasions charged him less for similar services. Expert opinion as to the value of the services may be given by physicians only; but juries are not bound to accept their valuation, and in case of different witnesses making different appraisals the lowest is most likely to be taken. Another possible defence is that the physician made more visits than were actually necessary; but the physician is recognized as the only judge as to the number and frequency of the visits required, and as a rule the physician remains in attendance on a case just so long as he deems it necessary, or until the patient dismisses him, or until he leaves by mutual assent. It may possibly be urged that the physician was intoxicated; this would be a good plea if the patient on this ground refused to allow the physician to treat him, but if the patient continues to receive that physician's services this defence will not be allowed. "Malpractice" is a common assertion; if proven it is a good defence; but to sustain this the defendant will have clearly to prove gross neglect or culpable lack of skill. With regard to "limitation of action," where there is only one item to the account, the matter is easily settled by referring to the Statute of Limitations for the particular State; but where, as is generally the case, there are several items, covering a number of years, with possibly certain payments made from time to time, the different States have decided differently on the question of this constituting a "mutual account." In this case proper advice must be sought. *R. J. E. Scott.*

FELL-O'DWYER METHOD OF INSUFFLATING THE LUNGS.—Insufflation of the lungs is evidently the most direct and instant method of restoring the suspended respiratory function, and yet until recent years it had been practically abandoned or forgotten by the medical world.

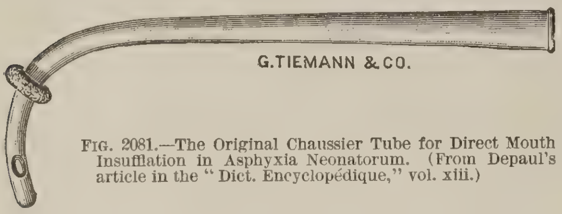

FIG. 2081.—The Original Chaussier Tube for Direct Mouth Insufflation in Asphyxia Neonatorum. (From Depaul's article in the "Dict. Encyclopédique," vol. xiii.)

Such was not, however, always the judgment upon it. It has an ancient and honorable history. Passing by the statement of Depaul that reference to it may be found in the Scriptures, and that Hippocrates considered it, he lets us know that Paracelsus (1493–1541) applied a bellows to the mouth and by its aid gently inflated the lungs, while Panarolus had recourse to the same procedure to revive the victims of charcoal fumes. Vesalius (1514–1564) demonstrated that in animals, after the thorax had been opened for observation, respiration could be maintained by the use of an insufflating bellows and tube.

In the latter part of the eighteenth century this method of relieving asphyxia was widely popular. It was in particular used to restore those who had been asphyxiated by drowning, and the numerous appliances, which were the product of the ingenuity of medical men in England and on the continent of Europe, were placed in the hands of life-savers and the police to be used at their discretion, or, too often, their indiscretion.

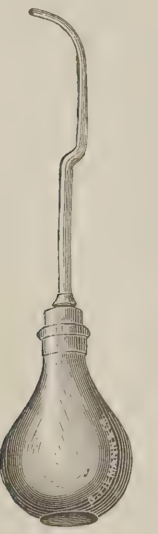

FIG. 2082.—Gairal's "Aërophore Pulmonique." (From Depaul's article.)

The names of many eminent physicians are connected with the invention of insufflating apparatus at this time. In all of these machines the air was supplied from a bellows or pump and injected into the lungs by means of a tube inserted into the mouth, the nostrils, or the glottis, or through a tracheotomy wound. In England William Hunter, Monroe, James Curry; on the continent, Des Granges, Hans Courtois, Fine, Pia and Garcy, devised instruments that were more or less widely adopted. And Lecat, Louis, Marc, Portal, Troja, and many others were warm in their praises of this method of treating asphyxia.

The indiscriminate use of these machines by ignorant persons resulted in bringing the method into disfavor. In 1829, Leroy d'Etiolles announced to the French Academy that the mortality from drowning had increased since this practice had become general. He contended that insufflation was dangerous to the integrity of the respiratory organs. Numerous experiments upon animals and upon human cadavers had convinced him that violent insufflation could produce emphysema and rupture of the air cells and smaller bronchioles. He therefore condemned the practice, and being supported in his conclusions by a committee, composed of Dumeril and Magendie, appointed by the Academy of Sciences to investigate the matter, the fate of insufflation was, for the time at least, sealed, in spite of the vigorous protests of Marc, the physician-in-chief of the life-saving service of Paris, and of other members of the Academy.

The sentence seemed final when, in 1845, Depaul started a propaganda in its favor for the resuscitation of the asphyxiated new-born. He demonstrated that insufflation was dangerous only when done by the inexperienced and with violence, and he proved that the human lung was more resistant than that of most of the animals used in Leroy's experiments.

Chaussier, who preceded him at the Maternité, in Paris, had, in 1806, recommended, for intralaryngeal insufflation, a tube which met the approval of Madame La Chapelle, and which Depaul adopted with some slight modifications.

The eminence of Depaul, the brilliancy of his argument, and the convincing character of his clinical evidence stimulated other inventors to attempt to improve upon his instrument. Gairal, in 1879, proposed an instrument which he called the "aërophore pulmonaire."

Ribemont, in 1877, presented a somewhat similar tube with *conical tip*, to which he too attached a rubber bulb.

Depaul, in his article, objects to these so-called improvements upon his method of insufflation, claiming that the operator's lungs are the safest form of bellows to use in filling the lungs of the new-born babe, and that the wedging of the conical tip of Ribemont might endanger the structures of the larynx.

Matas calls attention to the fact that Dr. Truehead, of Galveston, Texas, in 1869, described a complex machine of his invention for the purpose of inflating and aspirating the lungs. His article was contributed to the Berlin Obstetrical Society and appeared in their Transactions for 1869–72, but was never published in America.

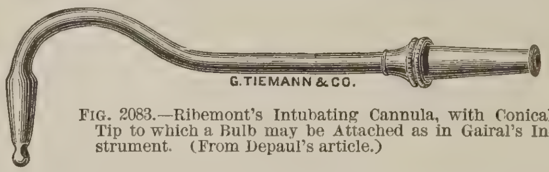

FIG. 2083.—Ribemont's Intubating Cannula, with Conical Tip to which a Bulb may be Attached as in Gairal's Instrument. (From Depaul's article.)

From this review, it is evident that the idea of combating asphyxia by means of insufflation was too fundamental ever completely to receive its quietus. Individual and original minds were attracted to it, but to the great body of the profession it was a discredited proceedure, when, in 1887, Dr. John R. Fell, of Buffalo, N. Y., after vainly trying every recognized method to maintain respiration in a case of opium narcosis, employed the tracheal cannula and bellows, used on dogs in the Buffalo Medical College, and succeeded, after carrying on respiration with its help for three hours through a tracheotomy opening, in saving the life of his patient. This success was followed by others, and in 1893, at the meeting of the Pan-American Congress in Washington, he was able to present a list of thirty cases whose lives had been preserved by the use of his instrument, which he had meantime modified by substituting a face mask for the tracheotomy cannula.

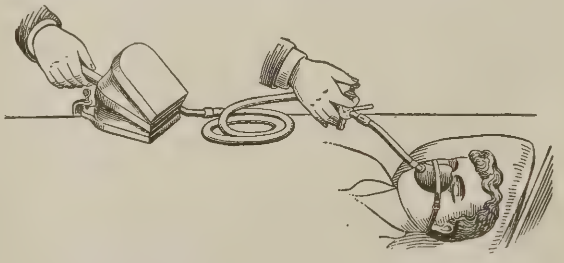

FIG. 2084.—Original Fell Apparatus, showing Face Mask and Air Valve Attached to Tube. (Truax's "Mechanics of Surgery.")

It is interesting in passing to notice that while the arguments of Leroy and his adherents had succeeded in discrediting insufflation for the relief of asphyxia in man, it had continued to be the universal custom in physiological laboratories to maintain respiration during

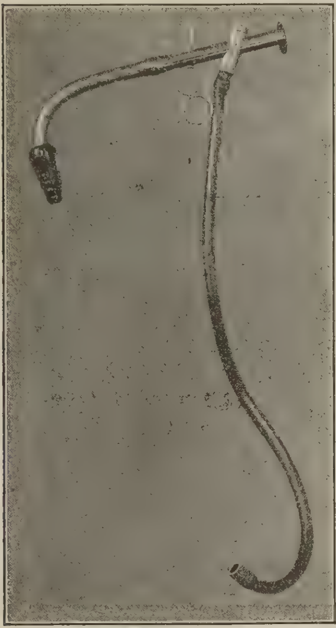

FIG. 2085.—Dr. Bloom's Latest Modification of the Intubator for Adults, with Automatic Ball-Valve.

vivisection experiments by injecting air through a tracheotomy tube by means of a bellows connected to it by rubber tubing.

The disadvantages of having to do a preliminary tracheotomy led Fell to substitute a face mask. But there were obvious objections to the latter, the chief of which was that part of the air was liable to pass down into the stomach and, by distending it, interfere with the descent of the diaphragm. Joseph O'Dwyer, whose experiments in intubation had admirably qualified him for the work, overcame these objections by the tubes which he constructed, for use with the bellows, and which he described in the *Annual of the Universal Medical Sciences* for 1894.

The tube and bellows, very properly called the Fell-O'Dwyer apparatus, have been in use in the Presbyterian Hospital, in New York, where they were introduced by Dr. William P. Northrup, since 1895, and in the Charity Hospital at New Orleans, for which they were purchased by Dr. J. D. Bloom, since 1896. Ample experience in the use of the apparatus in these two hospitals has demonstrated its great practical value. It consists of a foot bellows, connected by a long flexible rubber tube with the intubation attachment. The latter is of metal, is curved at the laryngeal end at a right angle, and has detachable conical tips, of various sizes to suit different ages, and designed to wedge in the larynx and prevent the escape of air alongside. The extra oral end has two branches, one to receive the tubing and admit the air from the bellows, the other to permit the escape of the air in expiration. The latter is stopped by the thumb of the operator during forced inspiration. No effort is made to aspirate the chest, it having been demonstrated during the days of Hunter and Monro that the elasticity of the lung is amply sufficient to expel the air. To give a better grasp on the instrument, a row of metallic rings is attached near the free end of the tube. These receive the fingers and give excellent control over the instrument.

Matas has recently modified the O'Dwyer tube by the addition of a pistol-shaped handle, and by adding a third branch, provided with a stopcock, through which an anæsthetic can be admitted without interfering with the continuance of forced respiration.

Since its introduction into the Charity Hospital, Dr. J. D. Bloom has made a number of improvements in the bellows, consisting of (1) a long lever to facilitate compression of the bellows; (2) a metal chamber, filled with cotton to filter the air on its way from the bellows to the lungs; (3) a similar chamber, through which oxygen can be passed into the bellows from a bag or cylinder, when deemed advisable.

For use in the asphyxia of the new-born, Dr. Bloom has had made a smaller tube, to which is attached the bulb of an ordinary atomizer, in place of the large bellows, thus preventing over-distention of the infant's lungs. In this small instrument the thumb of the operator is replaced by a ball valve, which automatically closes the exit tube when the bulb is compressed, and falls out of the way when the pressure from the bulb is stopped. (Fig. 2085.)

Since the days of Leroy the objections to the use of insufflating appliances have been: (1) That the instrument ignorantly or roughly used was capable of inflicting serious injury upon the larynx and upon the structures of the lungs themselves. To this it may be answered, as was done long ago by Depaul, that it is not intended to be either ignorantly or roughly used; that the same objections might be urged against any of the operations of surgery; and that extended experience in at least two great hospitals has demonstrated not only that it can be employed without danger to the integrity of the larynx and lungs, but that even after many hours of continuous insufflation by the Fell-O'Dwyer apparatus the voice is seldom affected.

(2) It is objected that it is difficult to introduce the tube into the larynx. It is true that a certain amount of dexterity is required, particularly in the infant, but the necessary skill is very quickly acquired. It is certainly far easier to introduce than the intubation tubes used in laryngeal diphtheria.

The instrument is introduced exactly as in the operation of intubation. The head of the patient is kept in the median line with the face pointing directly up. The mouth is kept well open by means of a gag, and the tongue is best pulled forward with a tongue forceps to bring the epiglottis well in reach. With the tube lightly poised in the fingers of the right hand the left index finger is passed along the tongue till the epiglottis and the opening of the larynx are felt. The epiglottis is hooked up by the

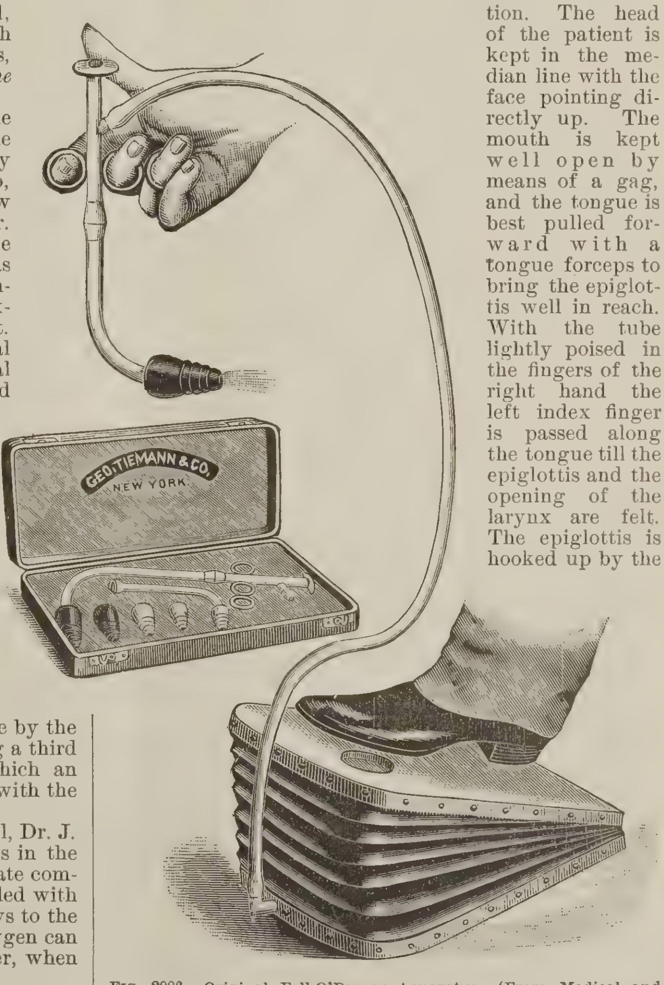

FIG. 2086.—Original Fell-O'Dwyer Apparatus. (From Medical and Surgical Reports, Presbyterian Hospital, of New York City, 1896.)

finger, which is slipped a little to one side. The tube is now passed alongside of the finger, exactly in the median line, till it reaches the tip of the finger. The handle is now sharply raised and the tube pressed home into the larynx. A gentle inflation from the bellows will cause the chest to rise and will be followed by expiration, if the tube is in the larynx. On the other hand, if it has passed down into the œsophagus, the chest will not rise, and in addition the air will be heard hissing in the throat. Occasionally the end of the tube gets blocked by the folds of the larynx. In these cases a little manipulation will generally clear it, or it may have to be withdrawn and again introduced. It is hardly necessary to say that these manipulations should be executed with gentleness and deliberation. The most common mistake is to see the operator frightened at a little delay in getting the tube in proper position and the inflow of air started. Seconds seem minutes in such cases, but it is very rare to see cyanosis develop which is not quickly cleared up when the bellows has been compressed once or twice.

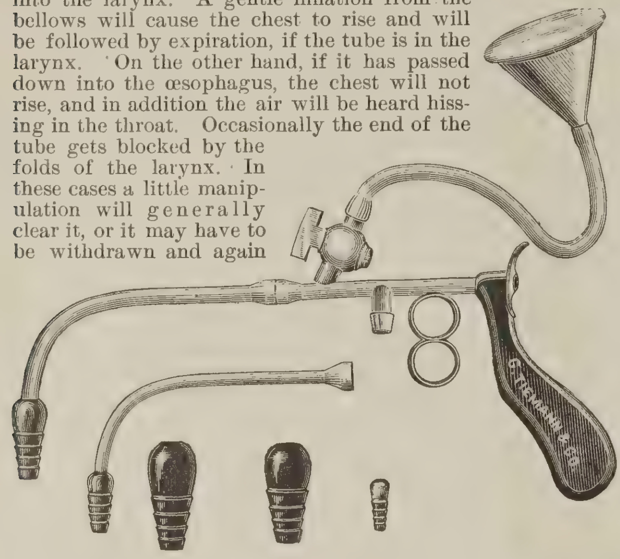

FIG. 2087.—Matas' Modification of O'Dwyer's Tube. (From his article on "Intralaryngeal Insufflation.")

The Fell-O'Dwyer apparatus is certainly the simplest and most efficient instrument so far invented for carrying on artificial or "forced" respiration. In 1897 Doyen ("Technique Chirurgicale") described an apparatus for insufflation, which he had devised for use in operations upon the thorax, to prevent the alarming symptoms of sudden pneumothorax. He was led to this invention by the experimental work of Tuffier and Hallion, Quenu and Longuet, who, recognizing the great danger from sudden pneumothorax, tried to find a way to prevent it. This they accomplished by insufflation, but they did not produce a suitable instrument. Doyen's apparatus is a credit to his inventive genius, but is manifestly inferior to the Fell-O'Dwyer apparatus.

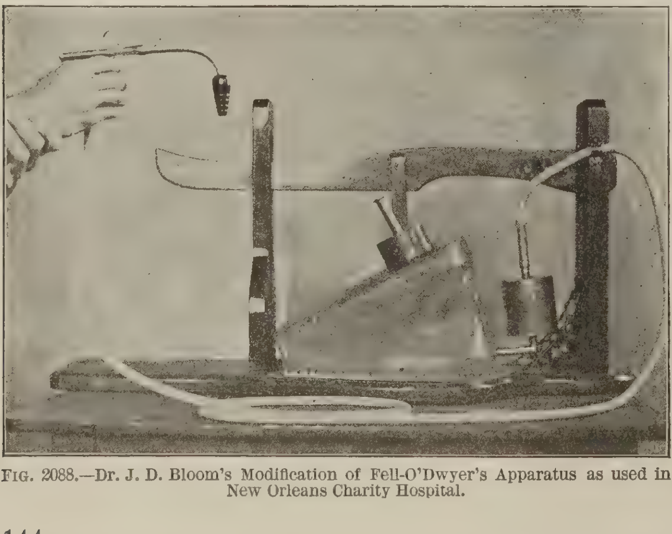

FIG. 2088.—Dr. J. D. Bloom's Modification of Fell-O'Dwyer's Apparatus as used in New Orleans Charity Hospital.

The latter is an admirably practical addition to our resources, and it is confidently recommended in the treatment of asphyxia in the following classes of cases:

1. In asphyxia neonatorum, by the use of Dr. J. D. Bloom's modification. The small size of the instrument permits its inclusion in any obstetrical bag. When its use is successful, the feeble and infrequent heart beat becomes more rapid and distinct. The skin loses its livid color and assumes the rosy hue of health, and even when no effort at independent respiration has been made by the infant the circulation appears to be perfectly normal. Generally a very short time elapses before the child can be left to carry on its respiration without assistance. I have myself now resuscitated too many asphyxiated infants with this instrument to feel any doubt of its superiority to any other method of meeting this condition.

2. In opium poisoning, with respiratory failure. This is the condition for which Fell originally recommended the method. Any one who has witnessed the transformation which occurs in the appearance of such a patient after the establishment of "forced respiration" with the Fell-O'Dwyer apparatus, and has compared its quiet efficiency with the strenuous and unsatisfactory effects of artificial respiration by Sylvester's and other methods, or with electrical stimulation of the respiratory function, will need no further argument to recommend it. Under its use the lividity of cyanosis is replaced by an unusually rosy color, the heart's action is improved, and, these two centres being kept going, the system has time to eliminate the poison. The use of the instrument is to be continued until, when the bellows is stopped, the patient breathes of his own accord at least twelve or fourteen times a minute and shows signs of being aroused from the narcotic stupor. We have frequently noticed that even after having regained consciousness these patients will lie quiet and permit the operator to carry on respiration for them. Sometimes after having regained the power to breathe for himself the patient will relapse and the tube will have to be again applied. At the Charity Hospital in New Orleans the apparatus has been used continuously for twelve or more hours, with ultimate success in saving the patient's life. It has undoubtedly saved cases which would have been fatal under other methods of treatment. It has markedly reduced the number of cases of post-narcotic pneumonia, which was formerly very frequent.

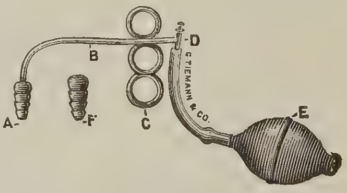

FIG. 2089.—Dr. J. D. Bloom's Adaptation of Fell-O'Dwyer's Apparatus for Use in Asphyxia Neonatorum. *A* and *F* are tips of different sizes; *D* is the ball valve to replace operator's thumb; *C*, metal rings into which the operator's fingers may be introduced; *E*, air bulb.

(3) In other cases of respiratory failure, as instanced by the following case: A young woman was brought into the Charity Hospital unconscious. She had been drinking long and heavily and appeared to be in a condition of alcoholic coma. No trace of opium could be found in either the stomach contents or the urine. The pulse was fairly good; respiration rapid and shallow. Suddenly the pulse became very feeble, the pupils became dilated and unequal, respiration practically ceased, and the skin quickly got blue. The pupils remained unequal for several hours afterward. Hypodermic stimulation and artificial respiration were at once resorted to, but she could not be made to

breathe. Death seemed imminent, when the Fell-O'Dwyer apparatus was introduced. In a few moments the pulse had slightly improved, and under the influence of the regular respiratory movements the cyanosis disappeared. After three hours she was sent to bed breathing for herself, and on the next day she was partly conscious. Total suppression of urine, however, terminated her life in coma.

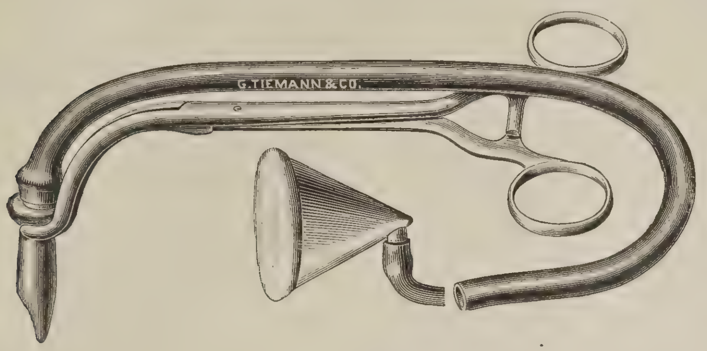

FIG. 2090.—Doyen's Intralaryngeal Tube and Rubber Connections, with Funnel Attached, for Laryngeal Tamponade and Chloroform Anæsthesia. The cut shows the special forceps used to introduce the tube. The intubating cannula may be used for direct air insufflation. (From Doyen's "Technique Chirurgicale," Fig. 43, p. 123.)

(4) In chloroform narcosis, when the respiration fails before the heart. Unfortunately, in most cases the heart fails along with the respiration, and then I believe nothing will save the patient.

(5) In the surgery of the mouth, to prevent the entrance of blood into the trachea and to secure free admission of air to the lungs, the anæsthetic being given through the tube; a very limited field of application, and one better met by preliminary tracheotomy.

(6) In thoracic surgery, when the pleura is widely opened and there is danger to life from the production of sudden pneumothorax, with collapse of the lung. As demonstrated by Parham at the Charity Hospital, in a case of sarcoma of the ribs, the frightful anxiety which attends this accident may be prevented by the use of the Fell-O'Dwyer apparatus, and the expansion of the lung quietly maintained while the organ is being secured to the chest wall by sutures.

There can be no doubt that the most brilliant future for this method of "forced respiration" lies in the field of thoracic surgery. Milton, of Cairo, has succeeded in doing some remarkable work upon the mediastinum with the assistance of insufflation, and Parham has, in this country, conclusively demonstrated its wonderful utility in forestalling the pneumothorax which has always been the bugbear of operative interference with the thoracic walls. *Erasmus D. Fenner.*

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FENNEL.—FŒNICULUM. The fruit of *Fœniculum. Fœniculum* (L.) Karst. ("*F. capillaceum* Gilibert," U. S. P.—fam. *Umbelliferæ*).

From a perennial or biennial herb with a tall, smooth, green, branching stem, and pinnate, skeleton-like leaves, the latter consisting of but little more than straggling, branching midribs and veins, arising from broad, concave, half-sheathing petioles. Umbels compound, naked, many-flowered. Native of Southern Europe, Western and Southern Asia, etc.; it exists in several varieties, and has been long and extensively cultivated.

Of two separate or united carpels, each 0.5 to 1 cm. ($\frac{1}{5}$ to $\frac{2}{5}$ in.) long, about one-third as broad and one-sixth as thick, oblong or a little narrowed at the summit, more or less curved, bearing five very prominent and stout light-colored ribs upon the back, otherwise smooth, yellowish or brownish-green; pericarp containing an oil tube between each two ribs and two upon the flat side; odor pleasantly aromatic; taste sweet and pleasantly aromatic.

Sweet, or Roman fennel, with very large, long, light-colored, pale-greenish fruits, and a particularly pleasant odor and taste, from cultivated plants of southern Europe, is much the best. German, or Saxon, with shorter and proportionately thicker fruits, is cultivated in Germany. Wild, or bitter fennel, is from wild plants growing in the south of France.

Fennel contains about three and a half per cent. of an *essential oil* very much like that of anise, being composed of a large proportion of *anethol*, a smaller one of a hydrocarbon of the terpene series, etc.

Fennel is a mild aromatic of exactly the same medicinal qualities as anise. It is, however, less used in medicine than that, but is considerably consumed as a flavor in cordials, as a spice and in veterinary practice. It also enters, as a carminative, to prevent griping, into the compound infusion of senna, and its oil similarly into the compound spirit of juniper and the compound licorice powder. Both are often added to prescriptions, with this object. The dose of fennel is 0.5 to 2.0 gm. (gr. viij.–xxx.). *W. P. Bolles.*

FENNEL, OIL OF—a volatile oil distilled from the above—is thus described in the Pharmacopœia:

A colorless or pale yellowish liquid, having the characteristic, aromatic odor of fennel, and a sweetish, mild, and spicy taste.

Specific gravity: not less than 0.960 at 15° C. (59° F.).

Between 5° and 10° C. (41° and 50° F.) it usually solidifies to a crystalline mass, but occasionally it remains liquid at a considerably lower temperature.

Soluble in an equal volume of alcohol, the solution being neutral to litmus paper; also soluble in an equal volume of glacial acetic acid.

The oil is not colored by the addition of a drop of ferric chloride T. S. (absence of some foreign oils containing *phenols*, and of *carbolic acid*).

If the oil be dropped into water, without agitation, it should not produce a milky turbidity (absence of *alcohol*). It should contain about sixty per cent. of anethol. The relatively higher temperature at which crystals of this substance begin to separate indicates its percentage and of course determines its quality. Another substance present in it is *fenchone*, with pinene, phallandrene, etc. Its properties and uses are precisely like those of oil of anise, and the dose is ♏ i. to v. The official water (*Aqua Fœniculi*), having a strength of one-fifth of one per cent., is usually employed as a vehicle, but is carminative in doses of 8 to 30 c.c. (fl. ℥ $\frac{1}{4}$ to 1). *Henry H. Rusby.*

FENUGREEK.—FŒNUM GRÆCUM. The seeds of *Trigonella Fœnum-Græcum* L. (fam. *Leguminosæ*), a very ancient food and drug of India, produced upon a cultivated and wild erect, branching herb. The seeds are about one-eighth inch long and nearly as broad, and a little more than half as thick. They are irregularly rhomboidal, with rounded edges, and grooved diagonally, on both sides. They are of a peculiar brownish-yellow, sometimes grayish-yellow, smooth, peculiarly and not very pleasantly odorous, and of similar fatty and bitter taste. About one-fourth of their weight is gum, nearly as much albumin, and there is seven per cent. of ash, with six of a disagreeable smelling and tasting fatty oil and a little resin. There are small amounts of *choline* (see *Hemp, Indian*) and *trigonelline* ($C_7H_7NO_2 + H_2O$). They are largely eaten as an albuminous food and are also regarded as tonic (doubtless due to the bitter alkaloid) and carminative. They are also very largely used in the ground state for poultices. The absorbable properties of the alkaloid, so applied, are unknown. They are very largely used as food and medicine for cattle, and this is almost their exclusive use in this country. The very young herbage is similarly used as a sort of *medicinal food*, much as are dock leaves and dandelion leaves. *Henry H. Rusby.*

FERMENTATION.—Fermentation is derived from the Latin *fermentatio*, which has the force of the root found in the Latin verb *fervere*, to glow with heat, to seethe, to boil—a good idea of which may be obtained from the English cognate *fervent*. The word was used to describe such processes as take place in a beer-vat or a jar of working preserves—processes which are marked by an elevation of temperature and the production of a scum or froth. (For a historical résumé of the work by which such processes were shown to be due to living organisms, see article *Bacteria*, this HANDBOOK, vol. i., pp. 677-680.) Later, the word came to be used in a wider sense to include putrefactive changes in general, and its use finally was extended to take in the processes which are now best known by the name of zymolysis (see article *Enzymes*, this HANDBOOK, vol. iii., p. 840). Fermentation, therefore, in its fullest significance may be said to include, on the one hand, those processes brought about by the lower vegetable organisms (bacteria, yeasts, moulds, etc.), which increase in growth as they produce the physical and chemical changes observed in the medium in which they grow; and, on the other hand, the term is sometimes stretched to include zymolysis or the changes produced by enzymes, which enzymes neither increase nor grow less as the process is continued.

It is interesting to note that while in Germany the word *Fermentwirkung*, of Latin origin, is used to apply almost exclusively to zymolysis, in England and in America the word fermentation is used to apply to exactly the other half of the field, viz., to those changes which are produced by the lower vegetable organisms.

In this HANDBOOK "Fermentation" has been practically treated by the articles on *Bacteria* and on *Enzymes*. As these deal respectively with each half of the subject, it will not be entered into *in extenso* here. There are, however, three classic theories, inseparably connected with the subject of fermentation, which have not been discussed in the articles referred to and which will therefore be taken up now. These are:

(*a*) Berzelius' theory of *catalysis*.
(*b*) Liebig's theory of fermentation.
(*c*) Pasteur's theory of fermentation.

Berzelius' theory of catalysis, while not advanced exclusively as part of a study of fermentation, was promptly seized upon to explain the action of enzymes, and is still so quoted—though rarely—at the present day. Prior to Berzelius' classic paper on this subject, it had been observed that certain substances such as finely divided platinum would cause the union of such stable elements as hydrogen and oxygen with the evolution of sufficient heat to cause the platinum to glow. Similarly such platinum would cause the oxidation of alcohol (in the presence of water) to acetic acid, and yet the platinum did not appear (as far as was known at that time) to enter into the reaction—at least it was not used up. Platinum was found, furthermore, to decompose hydrogen peroxide, and, what to Berzelius was still more striking, a flake or two of fibrin would have the same effect, the amount of hydrogen peroxide decomposed being considerable, while the platinum or the fibrin was little or not at all affected and apparently did not enter into the reaction (compare with illustration of nitric oxide, article *Enzymes*, this HANDBOOK, vol. iii., p. 839). To account for such phenomena Berzelius advanced the theory that certain substances could act simply by their presence and produce profound reactions, in which, *as far as he could see*, they took no part. Later investigations have shown there is probably no case in which a body acts in this way without taking part in the reaction and many severe criticisms of the Berzelian theory have been made, but it should not be forgotten that the theory was put forth only tentatively, and that Berzelius did not insist upon the discovery of a new force which could not be brought into line with other forces then recognized as active. This is clearly shown by the following translation from Berzelius' original paper (*Ann. de chimie et de physique*, 1836, vol. lxi., p. 150), in which he says: "This new force, which has been unknown up to the present, is common to both organic and inorganic nature. I do not believe it to be a force quite independent of the electrochemical affinities of matter; I believe, on the contrary, that it is only a new manifestation of these; but inasmuch as we are not able to see their connection and their mutual dependence, it will be more convenient to designate them by a separate name. I will call, then, this force, *catalytic force*. I will call, in the same way, *catalysis*, the decomposition of bodies by the force, just as we designate, by [the name] analysis, the decomposition of bodies by chemical affinity." From a comparison of this theory with the action of enzymes it may readily be seen how it was called in to explain zymolysis, but it need scarcely be said that the simple employment of the new word catalysis did not, in the slightest degree, explain the nature of the process.

Liebig went a step farther than Berzelius in attempting to show how ferments acted. He applied his theory to both organized ferments and enzymes. According to Liebig enzymes were albuminous in nature and possessed intramolecular movements or vibrations, which they tended to transmit to certain other (fermentable) substances around them. These fermentable substances, when they took up the vibrations in question, were shaken to pieces, and the atoms of which they were formed entered into new combinations. In the same way he supposed that the protoplasm of yeast cells, being highly complex and tending to break down, would transmit vibrations to non-living matter near them and cause it to break down.

Pasteur entered the field with a new theory, viz., that yeast cells, bacteria, etc., as a result of needs of their own in their life process, took from substances in solution around them what they needed—usually oxygen—and by this means destroyed the fermentable substance as such. The atoms which remained after the extraction of what the yeast cell needed then formed new combinations in accordance with their chemical affinities. This has often been compared to the yeast cell pulling out what might be called the keystone of the arch (comparing the molecule to an arch); the other stones of the arch, so to speak, would fall together in groups corresponding to the chemical affinities they possessed.

For a number of years the scientific world was interested in the discussion which followed between Liebig and Pasteur, until finally, by brilliant researches of his own and of others, Pasteur succeeded in making his theory the favored one. Among the many researches which might be quoted here was one by Dumas, which might almost be said to have given the *coup de grace* to Liebig's theory. Dumas showed that a thin film of collodion, not more than 0.1 mm. (about $\frac{1}{250}$ in.) thick, would absolutely prevent the action of an actively fermenting solution being transmitted to a fermentable solution on the other side. If Liebig's vibration theory was true, this was not what would have been expected, while it harmonized thoroughly with Pasteur's theory that the yeast cell would have to come in absolute contact with the fermentable substance in order to pull out the parts which it needed.

The theory of Pasteur, more or less modified as to the importance of oxygen in the process, might be said to be the one most generally held in favor, even at the present day; but more recent researches indicate that a new theory radically different will, not unlikely, take its place. This new theory is that the vegetable organisms so long identified with fermentation, and believed to be the efficient cause of the same, really act a secondary part—that is, they produce enzymes, and the enzymes bring about the changes to which we give the name fermentation or putrefaction. (See article *Enzymes.*) *George T. Kemp.*

FERN, MAIDEN-HAIR.—ADIANTUM. (*Venus-Hair Fern.*) *Adiantum* is a large genus of ferns, several of whose species have been used in medicine, more especially the *A. Capillus-Veneris* L. of Europe and the *A. pedatum* L., growing throughout North America, except the far North and the Southwest, and abundant also in parts of Asia. The herb is the portion used. It has an aromatic-bitter taste, due to constituents which have not been studied. Its use is historical, it having been employed mainly in the treatment of catarrhal affections, especially of the respiratory tract. At the present time it is largely used in the manufacture of some patent medicines, but scarcely in any other way.

Henry H. Rusby.

FERN, MALE.—ASPIDIUM. FILIX-MAS. "The dried rhizome of *Dryopteris Filix-mas* Schott and of *Dryopteris marginalis* Asa Gray (nat. ord. *Filicas*)" (U. S. P.)

The first-named of these species is a large, robust, and handsome fern. It is one of the commonest in the cooler parts of Europe, and abundant also in the temperate parts of Asia, in the northern and southern extremes of Africa, and in both North and South America. It is not found in the Eastern United States, but occurs in British America and in the Western States. Its employment as a tænicidal agent is of great antiquity, as it is mentioned by some of the earliest writers upon medicine. The introduction of the "oleoresin" (ethereal extract) dates from the recommendation of an apothecary of Geneva named Peschier, in 1825 (Flückiger). The horizontal or decumbent rhizome is collected and either dried and marketed in its natural state, or (as now usual) after stripping it of its dense coat of leaf bases and chaffy scales, then constituting the "Peeled Fingers."

DESCRIPTION.—Before being peeled, 10 to 15 cm. (4 to 6 in.) long by 5 to 7 cm. (2 to 5 in.) thick, including the densely imbricated, dark brown, cylindraceous, slightly curved stipe-bases and the dense mass of brown, glossy, transparent, soft, chaffy scales; when peeled, 1 to 2 or 3 cm. ($\frac{2}{5}$ to about 1 in.) thick, slightly curved or claw-shaped, somewhat narrowed toward one end, bearing several coarse longitudinal ridges and grooves, pale-green when first peeled, becoming pale-brown, or when too long kept, rusty-brown, smoothish (or somewhat roughly scarred with remains of the stipe-bases); texture rather spongy, pale-green, with age becoming gradually brown from the outside inward, the *Filix-mas* showing about 10, the *marginalis* about 6, steles in a loose and interrupted circle. The marginal hairs of the stipe-scales of *Filix-mas* consist each of two parallel, slender cells, neither of them glandular; those of *marginalis* are almost identical in appearance, being directed slightly more toward the apex of the scale, and their lower cell often a little narrower. Upon the older scales they are nearly wanting. Male fern has a disagreeable odor and a bittersweet, acrid, astringent, and nauseous taste.

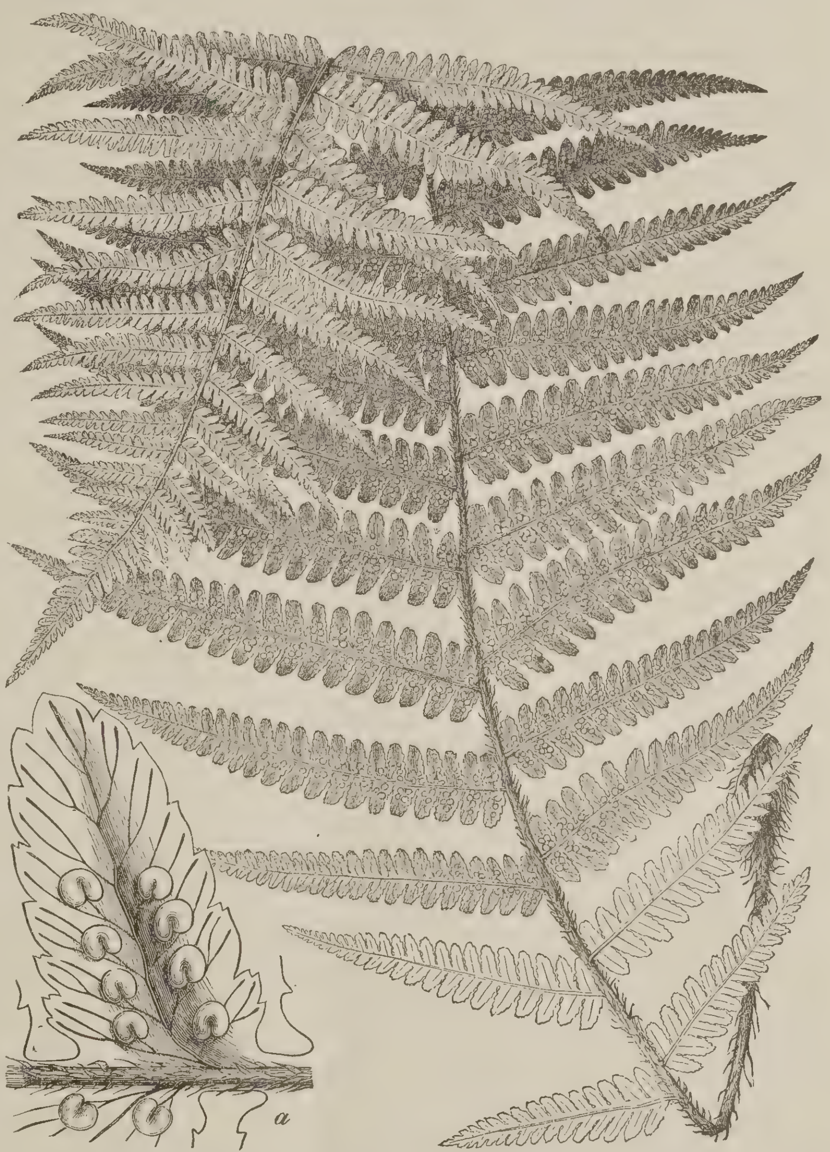

FIG. 2091.—Male Fern. Frond about one-third natural size; also a lobule (*a*) enlarged about four times, showing the round-reniform *indusia* covering the *sori.* (Luerssen.)

The chaff, together with the dead portions of the rhizome and stipes, should be removed, and only such portions used as have retained their green color. The powder should be freshly prepared and bright green.

Several, perhaps many, adulterants and substitutes have been and are sold. Some of these can be distinguished by their different numbers of steles, while the distinctions of others are microscopical and obscure. It is not indeed practicable, without a very elaborate description, to exclude all the possible adulterants. Some, not readily detected in the peeled drug, are so when the covering of stipes is present, a condition which is, for other important reasons, also to be preferred.

The second species occurs in Eastern and Northwestern North America. It is scarcely so large as the former.

Of late years, the market has afforded very much more male fern only a inch and a half in length by a quarter or a third of an inch thick, than of the larger sort. The size, however, does not appear to affect the quality greatly, except that the larger form retains its freshness longer.

Few drugs are more certain to prove effective than male fern of good quality and properly prepared, yet there are few whose preparations, as found in pharmacies, are more uncertain. The quality of the genuine drug appears to depend wholly upon its freshness and correct and careful preparation. The freshness is at once determinable by the color, and no pharmacist is excusable for accepting or using an inferior article. The outer surface at first loses its green, and assumes a very pale-brown, then a deep rusty-brown color. At the same time a similar change of color is occurring internally, beginning at the exterior and gradually working inward. The quality is in a general way proportional to the retention of the green color.

The composition of male fern is very complex and variable with the length of time that the drug is retained. Many compounds have been from time to time described and, being found to act more or less like the drug, have been credited as the active constituents. We are unable, however, to state positively to what the action is due. There appears to be little doubt that several of the constituents are active, upon both the system and the parasite. Filicic acid, which is certainly somewhat active, was long regarded as the chief tænicidal agent, but since it increases upon keeping the drug, while the latter becomes less effective, this view has become modified. Aspidin is more abundant in the fresh drug and has been proven to be active, as has aspidinin. With these substances occur six or seven per cent. of fixed oil, a variable amount of volatile oil and tannin, and various less known bodies. The 20% to 30% of *filicic anhydride* or *filicin* is not active.

In medicinal doses, 1 to 4 gm. (ʒ ¼ to i.) of the oleoresin, the preparation almost entirely employed, male fern ordinarily has a purely extraneous action, affecting only the parasite. But when very large doses are taken, or when absorption occurs, this being favored by the use of fats while the oleoresin is still in the intestine, for which reason castor oil is an ill-chosen adjuvant, poisonous symptoms may occur, and the results may be fatal. The symptoms of poisoning are those of great intestinal irritation and inflammation, purging and vomiting, convulsive movements and powerful depression, ending in coma. A favorable result from the use of male fern depends in great measure upon the method of administration. One of the most important points in its administration is the dietetic preparation of the patient. For ten or twelve hours before the first dose he should eat no solid food whatever, and the bowels if full should be emptied by a cathartic. Milk may be taken freely, or thin soup; then about 4 gm. of the oleoresin should be given at one dose; after several hours a second dose may be given, to be followed by a cathartic, if needed. The discharges should always be carefully examined for the head and upper portions of the worm. Unless these are passed the cure cannot be considered certain, and it may be found necessary to repeat the treatment. *Henry H. Rusby.*

FERN, SWEET.—This name has been applied to a number of plants; to some true ferns, because of their fragrance; and to some flowering plants with leaves resembling those of ferns, especially to the *Comptonia peregenia* (L.) Coulter (fam. *Myricaceæ*), also called Fern-Bush, Fern-Gale, or Sweet Bush. It is exceedingly abundant in rocky meadows, especially amidst blueberry bushes, in Northeastern North America. The leaves are peculiarly pinnatifid, with nearly semicircular segments alternating upon the two sides. They contain tannin, a small amount of an irritant glucoside, and a peculiar volatile oil, smelling like bay oil and somewhat like cinnamon. This oil has a specific gravity of 0.926 and solidifies at a freezing temperature.

The leaves are useful as a mild astringent of delightful fragrance, and are at the same time markedly stimulant, owing to the oil. The bark also contains tannin and is used as an astringent. The dose of the leaves is 1 to 2 gm. (gr. xv.-xxx.); of the bark, twice as much.

Myrrhis odorata Scop. (fam. *Umbelliferæ*) has also been called sweet fern. It is the sweet chervil of Europe and its root is used as a carminative. *Henry H. Rusby.*

FERNS.—(Nat. ord. *Filicineæ* or *Filices.*) This immense and interesting class of exquisitely beautiful plants has, unfortunately, but limited practical applications outside of decorative art. A few species yield extractible amounts of starch, while the rhizomes or young shoots of others are cooked and eaten. Dye-stuffs are yielded by a number, while several contain cumarin. There are many species which, although used to a large extent, and with good results, as domestic remedies, are not known to professional medicine. The commonest property, perhaps, is that of being anthelmintic, and many species of many genera, especially of *Pteris*, *Dryopteris* (incorrectly called "Aspidium"), and *Polypodium*, are so used. Many of these are poisonous, resembling in this respect the male fern. Next in importance are the astringent properties, due to tannin-like constituents, for which a very great number are in native use. In one or two cases, like that of *cibotium*, the hæmostatic effects are mechanical, after the fashion of lint. Many species are distinctly diuretic, and a few carminative, while a great number, like hart's-tongue or scolopendrium, are in use as pectorals. The gummy exudation from incisions in some of the South American tree ferns forms a most useful, permanent, and elastic protective covering to slight wounds. *Henry H. Rusby.*

FERNVALE SPRINGS.—Williamson County, Tennessee.

Post-Office.—Fernvale Springs. Hotel and cottages.

Access.—Viâ Louisville and Nashville Railroad to Franklin; thence 13 miles west to springs. Or viâ Nashville, Chattanooga, and St. Louis Railroad to Bellview; thence 12 miles southwest to springs. The location is 25 miles southwest of Nashville. This pleasant summer resort has been long and favorably known to the citizens of Nashville and the surrounding country. It has recently been thoroughly renovated, and it is said that guests as far away as Texas are beginning to find their way to Fernvale. Many attractions are afforded to the visitor in the picturesque hilly and wooded districts surrounding the springs. The situation of the resort is about 1,400 feet above the sea-level. The springs here are six in number, only three of which are mineralized. An analysis was made in 1836 by G. Froost, analytical chemist, and in 1879 by Prof. W. T. Lupton, of the Vanderbilt University. The former analysis is antiquated and incomplete. Following is Lupton's analysis:

One United States Gallon Contains:

Solids.	Grains.
Potassium sulphate	1.14
Sodium sulphate	13.76
Sodium sulphite	8.30
Sodium chloride	8.85
Lithium carbonate	Trace.
Calcium sulphate	27.63
Calcium carbonate	7.04
Magnesium carbonate	6.52
Iron oxide and alumina	.55
Silica	.05
Total	73.84
Gas.	**Cu. in.**
Sulphureted hydrogen gas	14.21

This water is very clear and not unpleasant to the taste. It has proved to be efficacious in skin affections of the squamous variety and in disorders of the alimentary tract and kidneys. It is also used locally in the treatment of sore eyes, chafing of the skin, superficial ulcerations, etc. *James K. Crook.*

FERRIS HOT SPRINGS.—(Formerly Matthews), Gallatin County, Montana.

POST-OFFICE.—Bozeman. Hotel. These springs are located on the east bank of the West Gallatin River, 7 miles west of Bozeman, from which place they are reached by coach. They were discovered over twenty years ago, but were not much improved until quite recently. The present proprietor has erected a handsome modern hotel, improved the natural charming surroundings, and placed the resort on a par with the most attractive in the West. The location of the hotel possesses unusual advantages. To the northeast and south a broad expanse of level country stretches out, dotted here and there with groves of cotton-wood and poplars, the intervening ground being occupied by fields of growing grain and verdant meadow lands. On the west the river sweeps along in magnificent curves, the line of tall trees conforming to the meanderings of the stream. Back of all, the grand old Rockies—snow-crowned, rock-ribbed, majestic—form an apparently unbroken guard to the enchanting scenes which lie in tranquil loveliness below. The location is 4,500 feet above the sea-level. Fish and game are found in great abundance and variety in the neighborhood. An analysis of the waters by Messrs. Riggs and Clark of the United States Geological Survey in 1885 resulted as follows:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Silica	4.61
Sodium silicate	6.40
Calcium carbonate	2.28
Magnesium carbonate	.21
Sodium carbonate	4.37
Potassium chloride	.78
Sodium chloride	4.12
Sodium sulphate	11.51
Loss	.06
Total	34.34

The analysis shows sufficient sulphate of soda to give the waters a laxative effect when taken in considerable quantities. They are recommended, both for internal use and for bathing, in the diseased conditions to which hot saline waters are applicable. *James K. Crook.*

FEVER. See *Calorimetry.*

FEVER, CLINICAL SIGNIFICANCE OF.—By fever we understand an abnormal elevation of the temperature of the body continued for a number of hours, or if not continuous, at least intermittently repeated, due to some infection or to some local inflammatory process, or to some unexplained disturbed state of the nervous system.

No symptom of disease was more carefully studied by the ancients than the temperature, and from the time of Hippocrates to the eighteenth century it was estimated by the rate of the pulse. Early in the eighteenth century Boerhaave began to use the thermometer in fever cases, but the thermometer did not come into general clinical use until Gavarret, in 1839, and twenty years later Zimmermann, Traube, and Wunderlich urged its advantages.

During the next twenty-five years the prognostic value of the height of the temperature became more and more over-estimated, but during the last fifteen years its prognostic importance has become much better understood, and to-day its greatest significance lies in its diagnostic advantages as a day-to-day indicator of the progress of the disease.

To understand well the pathology of fever, it is necessary to remember the normal mechanism of animal heat. The sole cause of this heat is a process of combustion of food substances by the oxygen absorbed. About four-fifths of the total body heat is produced in the skeletal muscles through an oxidation whereby oxygen is absorbed and carbonic acid given off, though the processes passed through are probably much more complex than mere oxidation. The other one-fifth of the animal heat is furnished by the secreting glands and the alimentary canal during digestion, and the liver, the largest gland of the body, contains the warmest blood. The internal temperature will be higher during the digestion of a meal than before.

During active fevers glandular activity and digestion are at a low ebb, and almost the entire heat production in these conditions is due to oxidation or changes in the muscular system; hence the loss of weight. Any muscular or mental activity or the taking of food will slightly raise the temperature, but external surroundings do not much affect the temperature of adults. But the adult during convalescence from a severe sickness is easily made colder or warmer by sudden changes in the external air or by any internal disturbance, the heat-regulating apparatus having become temporarily impaired. The babe, also, has its temperature easily raised or lowered by external or internal conditions because its heat-regulating apparatus is undeveloped.

Strychnine, caffeine, cocaine, and atropine all raise the temperature by increasing muscular and cerebral activity, the latter by reducing heat loss by preventing perspiration. Alcohol, nicotine, and morphine diminish temperature, the first two by relaxing the blood-vessels and increasing perspiration, and the latter by preventing all glandular and muscular activity.

Clinically, then, with high fever we should stimulate with alcohol, but with depression we should stimulate with strychnine.

A word as to the physiology of heat regulation. The equilibrium of the body temperature must be governed by the relation of the heat loss to the heat production, and as the one increases, so must the other, and all of this mechanism must be under the control of some finely adjusted nerve governor. The theories which have been offered in explanation of this are very various; they range from Macalister's three centres, namely, a thermogenic or heat-producing centre, a thermolytic or heat-dispersing centre, and a thermotaxic or heat-controlling centre, to Schaefer and Moore's belief that the vaso-motor mechanism in the medulla oblongata is probably the regulator of the relations of heat loss to heat production. Ott's cortical heat centre and Reichert's corpus striatum centre have not been proved, no structural difference having been discovered before and after the heat-regulating power has developed. But this power appears to be associated with the control over the skeletal muscles and blood-vessels.

As to the pathology of fever, its cause must be an over-production of heat, or a diminished loss of heat, or both. This may be due to anything that interferes with the vaso-motor regulating apparatus, or to anything that increases chemical activity, be it glandular, muscular, or metabolic.

Probably most fevers are due to poisoning from some source, the character of the fever, of course, depending upon the kind of poison. Anything that irritates or excites the brain may interfere with heat regulation and cause fever. This is especially noticeable in convalescents and in infants in whom too much excitement, over-eating, etc., cause a return of fever in the convalescent, or a febricula in the infant.

The purest kind of nervous pyrexia is seen in hysterical fever. This may be caused by hyperfunctional activity of some of the control centres, or we may have such a nervous shutting up of the peripheral blood-vessels as greatly to diminish the heat loss. Also the unceasing muscular activity present in some hysterical explosions, either as muscular or as simple fibrillar contractions, increases the heat production without adequate increase of heat loss.

A malarial paroxysm is perhaps the best type of immediate stoppage of heat loss and the consequent enormous sudden rise of the temperature. As the infected red blood corpuscles burst from the pressure of the matured plasmodia the first impression on the nervous system is to cause a sudden irritation of the vaso-motor centres and the resultant contraction of the peripheral vessels, and the symptom is a chill more or less severe. The internal temperature, perhaps partly from the toxin, perhaps largely from the obstructed heat loss, rises rapidly and often to a great height, which is sustained until the now superheated skin and over-stimulated sweat glands begin to pour out a profuse perspiration and heat loss first exceeds and then equals heat production, and the normal equilibrium is once more established. A period without fever, the intermittent stage, then follows, its length depending upon the type of plasmodium with which we are dealing.

In the same individual may be found mixed varieties of malarial parasites, maturing at different and at irregular times, and one set so overlapping the other that we have the so-called remittent fever—a malarial fever with remissions but without any marked intermissions. A frequent use of the thermometer, however, will generally show some short period of intermittency.

Our best type of a continued fever, of course, is typhoid. This fever undoubtedly becomes in time a mixed affair. Very soon in the course of this fever, unless laxatives and bowel antiseptics are freely given, fermentation and decomposition occur in the intestines, and we have an increased temperature due to the absorption of toxins from these processes, and the infection is then double.

This same double infection occurs in diphtheria, when added to the mild fever caused by the diphtheria bacillus we have fever from the absorption of the putrefactive products from decomposition of the diphtheritic membrane. The same is true of scarlet fever with decomposing membranous exudation on the tonsils.

In acute colds, follicular tonsillitis, measles, and chickenpox the fever is short-lived unless some complication occurs. The specific germs may so shock the nervous system as to produce the premonitory chill, and this in turn will be followed by a fever which, however, soon terminates unless some focus of pus formation develops, or the secretions undergo putrefaction, or the fæces become impacted.

The hectic fever of chronic tuberculosis is a pus fever, that is, a streptococcus fever, and is not caused by the tubercle bacillus.

Of all irregular and intangible fevers la grippe heads the list. The germs of this disease can cause a typical chill which is followed by a high fever that lasts two or three days and is followed by more or less nervous depression and by catarrhal symptoms; but the vaso-motor system is profoundly affected, often for a long time, and irregular chills, shiverings, hot flashes, and even hemorrhages from the mucous membranes may occur. In no fever is the insomnia so noticeable as in influenza, undoubtedly due to the inability of the blood-vessels of the abdomen properly to dilate and thus relieve the cerebral congestion and produce sleep—in other words, a general vaso-motor ataxia is present.

Fevers are classified as: (1) Continued, (2) remittent, and (3) intermittent, according to the character of the temperature range.

A continued fever is one in which there is but slight deviation in the temperature line. A remittent fever is distinguished by intense paroxysms. In the intermittent type we have paroxysms of fever with absolute intermissions, or periods of apyrexia.

Fevers are also sometimes classed as dynamic or sthenic, and as adynamic or asthenic, in accordance with the tone of the heart and nervous system.

Sthenic fever is characterized by a hard, full pulse, a flushed face, and often active delirium. The crisis in these cases is generally positive and short.

In an asthenic fever the pulse is from the beginning feeble and compressible, the skin is pale and often moist, the respiration troubled, and if there is delirium it is of the low muttering type, and the patient seems to die rather from exhaustion than from the lethal power of the disease.

To study the range of temperature carefully in a given case of fever the thermometer should be used at perfectly regular intervals.

Fevers are often divided into four stages: First, a period of incubation extending from a few hours to a week; second, the stage of invasion; third, the fastigium, or stage of greatest power of the disease; fourth, the stage of declination or defervescence.

The stage of invasion may be ushered in by a chill or by shiverings, and in the case of children often by convulsions, or by vomiting, or by both. The surface of the body, especially the extremities, tip of nose, etc., is cold for a short period, this stage being soon followed by myalgias, constipation, loss of appetite, thirst, and a more or less heavily coated tongue. The stage following is one in which the temperature and pulse become higher and higher. This stage terminates either by crisis or lysis. In crisis the temperature falls in the course of from twenty-four to thirty-six hours to the normal, and the other symptoms undergo a similar decline. Such a sudden decline of the fever may be attended by shock; hence this period is one of considerable danger. At this time we may expect hemorrhages, diarrhœa, profuse perspiration, weak heart, and collapse. The course of a lobar pneumonia furnishes the best example of a fever ending by crisis.

When the declination is by lysis, several days are generally occupied in the process, the morning remissions becoming more pronounced from day to day and the evening rise being less than that of the day before. This is typical of the declination of typhoid fever.

A sudden fall of temperature at an unexpected time in the disease shows that something serious is taking place, and is almost always a bad omen. A sudden rise, on the other hand, generally shows that some complication has occurred, and the case must then be carefully studied.

Before we consider the necessity of treating a fever, —that is, of simply lowering the temperature of the patient's body,—we should analyze its cause and should carefully weigh the danger, if any, which threatens the individual. In the first place, it is a question whether the fever does not represent nature's method of combating the harmful influence of the toxic products of the disease germs. On the other hand, however, there must be taken into consideration the question of how much fever the human body can safely bear. It is permissible to state that the system can sustain for a short time a temperature of 105°, or even 106° F., without danger or damage, while a long-continued temperature of 101° F. or over seriously threatens the integrity of the heart, muscles, and nervous system. With a short-lived fever, as of a malarial paroxysm, or the grippe, or a cold, if the fever is high it may cause some symptoms that are very uncomfortable and may call for some treatment, but the temperature as such requires no treatment.

The symptoms of high fever are myalgia, especially backache, generally localized in the lumbar region, headache, rapid heart action, and quickened respiration. Delirium may or may not occur, according as the patient is or is not susceptibile to irritation from cerebral congestion. The tongue is dry, and the mouth and lips are parched, not only from the fever, but from the mouth-breathing that is present if the lungs are much congested by a disturbed circulation. The surface vessels are more or less contracted as shown by the dry skin and the tendency to hemorrhages manifested by the mucous membrane. The internal organs, especially the liver and spleen, generally become congested. The liver thus becomes impaired in its power to produce materials protective against the toxins, and hence is unable either to render the poisons of the specific germs innocuous or to neutralize the effects of the toxins which are absorbed from the intestines.

Furthermore, owing to its congested state, the liver will secrete a diminished amount of bile, and thus there will be established a tendency to constipation and to fermentation in the intestinal canal. These changes, coupled with those which follow the diminished production of hydrochloric acid in the stomach, may lead to vomiting and to intermittent diarrhœa.

Aside from the fact that it easily becomes congested we cannot state what effects are produced in the spleen by fever.

From what has already been stated it is apparent that no serious harm can come to the organism provided the fever be short-lived. Hyperæmias give place to normal vascular conditions, toxins are eliminated, and all that we need do is to hasten nature's cure by increasing the loss of heat through the employment of any measures which tend to relax the peripheral blood-vessels and to cause perspiration. It is also possible that, in the effort to secure this result, we may derive some aid from the administration of a cathartic or from cold applications to the head.

If, on the other hand, the fever is a continued one, or even continuous for a few days, then we must analyze the condition. If we decide that this amount of fever is due to the specific germ and its associated local inflammatory conditions, our duty is to keep the patient as quiet as possible. The importance of this becomes apparent when we consider that every excitement causes restlessness, and this in turn means muscle movements through which heat production is increased. Hence it will frequently be necessary to give hypnotics. The bowels should be daily moved, not only for the relief of the liver, but to prevent fermentation, decomposition, and the absorption of all of the products of bowel infection. A carefully regulated ingestion of iced or cold water also tends to diminish the temperature, but if the latter still keeps too high we can, in short fevers, reduce it by means of the coal-tar products, cautiously administered in appropriate doses, or, in long-continued fevers, by cold applications.

If the body-temperature is so high as to be dangerous to life, even though brief in duration, as occurs in insolation, no treatment is as successful as immersion in cold water made gradually colder by ice. If the heart can withstand the previous high temperature, under this treatment the vaso-motor system recovers and heat control is re-established.

If after careful survey of the case we decide that the fever is in excess of that due to the disease *per se*, we must search for the additional cause, and with each disease we know where to seek its local manifestations. In the varied local inflammations such an abnormally high body-temperature generally indicates the formation of pus, as in appendicitis, pleuritis, synovitis, or otitis media. In typhoid fever and dysentery it means ulcerations with decomposing membrane and sloughing, and the absorption of toxins and pus products. In tuberculosis it means some closed up or incompletely evacuated pus cavity,—*i.e.*, streptococcus fever. In diphtheria, in follicular tonsillitis, and in scarlet fever it means a putrid exudation, a decomposing membrane, and a poorly cleansed throat.

While it is good treatment to keep the bowels free from fermentation and putrefaction in all short-lived fevers, it is absolutely essential in typhoid fever, and any treatment that gives free daily movements of the bowels in this disease will favorably modify the course of the fever. In typhoid fever constipation keeps the partially digested milk or other nutriment long in the intestines, and the mucous deposits and ulcerative sloughs long remaining *in situ* become most productive culture grounds for all sorts of bacilli and cocci, and the colon bacillus is often stimulated to migrate. Also fermentation increases, gas is formed, and tympanites, with the danger of perforation and hemorrhage from distention, readily occurs. We then have secondary infection with high fever and cerebral toxæmia.

If every local inflammation that develops in the course of any fever is kept as clean as possible, if the skin is kept in good condition by hot or cold sponging as the case may require, if plenty of water is given to drink, and if the bowels are kept nicely opened, there will be very little call for the use of so-called antipyretics, and the non-use of such drugs will allow a more careful study of the temperature curve, and therefore a better understanding of the case. *Oliver T. Osborne.*

FIBRINOUS BRONCHITIS.—(Synonyms: Croupous, exudative, plastic, pseudo-membranous, bronchitis; Ger., *Bronchialcroup, croupöse Bronchitis;* Fr., *Bronchite pseudo-membraneuse.*)

DEFINITION.—An acute or chronic inflammatory affection of the bronchial mucous membrane characterized by the deposit of plastic matter which becomes detached and is expectorated in the form of moulds or casts of a more or less extensive portion of the bronchial tree.

CLASSIFICATION.—A distinction must be made between true fibrinous bronchitis, a comparatively rare disease, and those conditions in which the expectoration of similar moulds results from (1) an accumulation of clotted blood in the bronchi, as in hæmoptysis, (2) the extension of a plastic formation from the upper respiratory passages, as in diphtheria, or (3) the upward extension of the fibrinous exudate in acute pneumonia. The term bronchial polypus was applied to all these conditions, as well as to the disease under consideration, by many of the earlier writers from Galen[1] down to Laënnec[2] and Cheyne[3]; many indeed regarded the casts as pieces of flesh. Cheyne was one of the first to make a distinction between casts of hemorrhagic origin, mere coagula of blood "moulded into shape by the bronchial vessels," and those due to an inflammatory process.

Strümpell[4] classifies the disease into a true, essential form, or that which attacks persons who were previously healthy, and a secondary, symptomatic form, which occurs in those who have already suffered from some other disease, especially chronic pulmonary affections. An acute and a chronic form are recognized, but, although they differ very obviously, it is not always possible to assign a present case to one or the other class until its full clinical history has been revealed.

ETIOLOGY.—No specific etiological factor has been determined. It is quite probable that the exciting cause is not the same in all instances, so various are the conditions under which the disease occurs. It is encountered at all times of life from infancy to old age, but seldom before the tenth or after the fortieth year. Hayn[5] records a case with autopsy in a new-born child, and W. R. Brown[6] saw it in a man of seventy-four years, with recovery. The essential form is not frequent in childhood, many reported cases having been merely complications of diphtheria. Morrill[7] states that of seventy-six cases only eleven occurred in children of twelve years or under. It is about twice as frequent in men as in women, but attacks male and female alike in childhood. More cases have been observed in England, Germany, and Switzerland than in France, Italy, or the United States, and in the late springtime than at any other season (April and May—Beschorner; May and June—Eichhorst). More than one member of the same family has been attacked—Watson's two cases were in brothers,[8]—and Pichini[9] observed three simultaneous cases; but neither hereditary nor endemic influences have been demonstrated. Personal idiosyncrasy is probably a more important factor (Mason[10]). Robust individuals are sometimes attacked, but more frequently those who have been debilitated by some previous illness such as typhoid fever, pneumonia, measles, scarlatina, or other acute infection. The disease has occurred during pregnancy and in the course of typhoid fever, and the menstrual periods have apparently borne some etiological relation to it in some cases. The recurrences in Schnitzler's case of twenty-four years' duration occurred regularly for several years at the menstrual periods, but continued long after the menopause. Its association with such cutaneous affections as impetigo, herpes, and pemphigus has been repeatedly observed. Most of the subjects have been anæmic, and many have been the victims of syphilis, tuberculosis, rickets, or alcoholism. Six of Model's seven cases were tuberculous.[11] Its association with other diseases has no doubt been merely accidental in many instances. The disease is not contagious, and we have no direct evidence that it is infectious. The bacteriological investigations have been too few to aid us in the solution of this question. In some instances it has been attributed to the Klebs-Löffler bacillus, but Escherich[12] failed in his attempts to demonstrate this bacillus in the bronchial mucus or to inoculate animals successfully with the membrane. Pichini cultivated three varieties of bacteria, and reports that by the injection of pure cultures of them into the tracheas of animals he succeeded in producing a condition very similar to bronchial croup. Various micrococci found in the secretions by other investigators probably bore no relation to the disease, although Sokolowski[13] reported four acute cases which he considered due to the presence of the Staphylococcus albus and aureus.

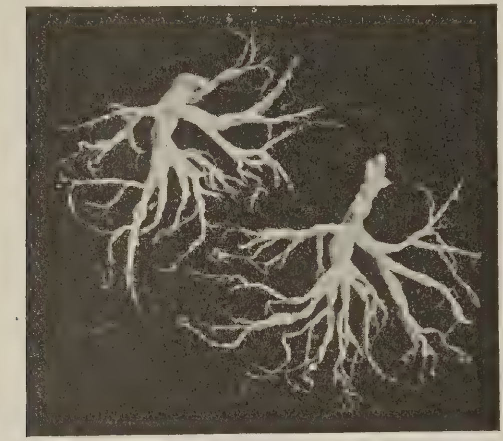

FIG. 2092.—Fibrinous Casts Photographed by the Author from Specimens Obtained from a Case Coming under his own Observation. (Three-fifths natural size.)

PATHOLOGY.—Hyperæmia and swelling of the bronchial mucous membrane have been found in most of the cases examined after death, but the autopsies have been few. In some instances the epithelium was intact, in others it had been lost. Casts when present were more or less firmly adherent to the bronchial walls or lay detached within their lumen. In acute cases there was often evidence of extensive inflammation reaching from the trachea to the terminal bronchioles, while in most chronic cases the disease had been confined to one or more isolated regions.

The casts (Fig. 2092), pure white or of a cream color, sometimes streaked with blood, are firm and very elastic in consistence. They correspond in size and contour to the lumen of the bronchial tree, branching dichotomously, and extending, as a rule, to the finest branches. They vary in length from 5 to 15 cm. The main stem is cylindrical, from 0.5 to 1.5 cm. in diameter, and corresponds to the second or third subdivision of the bronchus. It is either patulous or is filled with mucus. The smallest branches are generally compact, those of intermediate size contain air. From the presence of small masses or nodules at the extremities of the terminal branches or along their sides (Fig. 2093) it has been inferred that the plastic formation had extended into the infundibula. Transverse sections of the largest branches have to the naked eye a lamellated appearance, and the microscope reveals superimposed layers of a delicately fibrillated substance. In the meshes of this tissue various cellular elements are found—epithelium, leucocytes, oil globules, and sometimes red blood corpuscles. In the smaller branches Charcot-Leyden crystals and Curschmann's spirals are sometimes seen. Klebs[14] attributes the formation of casts to increased transudation into the alveoli arising from dilatation of blood and lymph vessels, and Eppinger[15] thinks that they are due to the escape of blood serum rich in fibrin into the bronchial tubes.

The chemical structure of the casts has not been definitely determined, although they have generally been regarded as composed of fibrin. Strümpell found that the Weigert fibrin stain had no effect upon them. Beschorner[16] reports two cases examined by Neelsen, in which they were composed chiefly of mucin; Grandy[17] found mucus alone, and Herzog[18] proved them to be definitely fibrinous by the characteristic fibrin stains and particularly by the peptic test. From these different results and limited personal investigation it seems probable that the casts are not always the same in chemical composition, or that they are composed of a substance closely related to both fibrin and mucin, but not identical with either of them.

SYMPTOMS.—The acute form may have a sudden, severe onset, with high fever, chill, dry cough, dyspnœa, and constriction of the chest, but in most cases it begins as a simple acute bronchitis, with cough, scant expectoration of clear mucus, and possibly a slight elevation of temperature. In children it is often preceded by malaise. Much difference is noted in the severity and abruptness of the initial symptoms in different cases. A chill may mark the transition from the simple to the fibrinous form. The pulse rate is accelerated, partly perhaps as a result of interference with the bronchial circulation. With the development of casts the cough becomes more harassing and paroxysmal, and the dyspnœa and substernal constriction become more pronounced. A more or less profuse hemorrhage sometimes accompanies or follows their expulsion. A most gratifying relief follows the removal of the obstruction, but it is transitory and the paroxysm may recur within a few hours. The casts are sometimes extensive. Niemeyer[19] records the case of a girl fifteen years old who for several years expectorated almost daily an entire cast of the left bronchial tree. In severe cases digestion becomes impaired, nutrition is interfered with, and great nervous irritability may be exhibited. Recovery takes place by a gradual subsidence of the symptoms; the casts no longer appear, the temperature, although high, rapidly declines, appetite and strength return. Fatal cases generally terminate in from three days to two weeks, sometimes suddenly by suffocation.

The chronic form generally follows a more or less protracted bronchial catarrh. Its course is one of exacerbations and remissions. Paroxysms of cough, dyspnœa, and constriction occur, to be followed by temporary relief when the casts are expelled. The paroxysms may be of short duration, but they recur at longer or shorter intervals for weeks, months, or years. Walshe[20] records a case of seven years' duration, Schnitzler[21] one of twenty-four years, and Kisch[22] one that lasted twenty-five years. Every grade of severity is seen in the recurrences, and months or years of perfect health may inter-

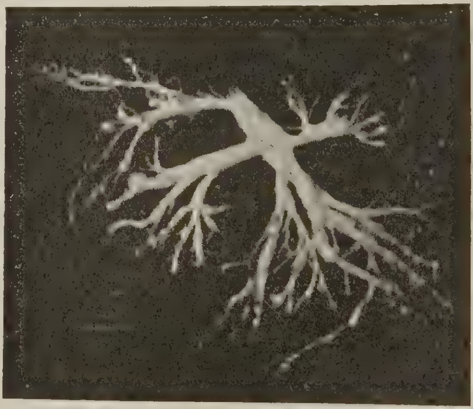

FIG. 2093.—Fibrinous Cast from Case Represented in Fig. 2092, and Showing Nodular Masses Supposed to have Come from Infundibula. (Three-fifths natural size.)

vene. Only a limited area of the bronchial system is involved in most cases, and the casts that are coughed up from day to day may be almost identical in size and form. The temperature rises, if at all, during the exacerbations and does not generally reach so high a degree as it does in the acute form.

The physical signs are exceedingly variable in both types of the disease and depend for the most part upon the presence or absence of casts in the bronchi at the time of examination. Retraction of the intercostal spaces and diminished respiratory excursions on the affected side have been noted. In acute cases we may find all the evidences of an acute bronchitis; in the intervals of quiescence there may be no adventitious signs. Percussion is usually negative; if, however, a considerable portion of the lung has undergone collapse as a result of the plugging of its bronchi, corresponding dulness will be elicited. A tympanitic tone has been more frequently noted, and is to be expected over the other parts of the lung in the presence of atelectasis. The results of auscultation are equally uncertain. Every variety of râles, from the sonorous and sibilant to the fine subcrepitant, may be heard, and blowing, rasping, rattling, and flapping sounds have been described. Over a collapsed area the normal vesicular murmur is replaced by bronchial breathing, and the vocal resonance is intensified. Flint[23] regarded the subcrepitant râle, confined to a limited area and not diffused as in capillary bronchitis, of value in the diagnosis. Escherich was able to see the fibrinous coating of the trachea surrounded by a hyperæmic and swollen area of mucous membrane in the laryngoscopic mirror, but as a rule the diagnosis rests solely upon the expectoration of the characteristic fibrinous moulds. To recognize these the sputum must be dropped into water where they unfold from the mass of mucus in which they are usually embedded. It is possible that the disease is sometimes overlooked from failure to make this test or when, as often happens with children, the sputum is swallowed.

Prognosis.—A guarded prognosis should always be made in acute cases. Strümpell places the mortality at twenty-five per cent. If, however, those cases are excluded in which the disease is merely a complication of another, perhaps more serious, disorder, neither the acute nor the chronic form can be regarded as in itself extremely dangerous. Recovery is the rule in chronic cases, but the duration of the immunity is uncertain. Much depends in either type upon the physical condition of the patient. The prognosis is, therefore, much more favorable in the primary form than in the secondary. High temperature is always to be regarded with suspicion if it persists through the intervals between the paroxysms, as it may indicate the development of pulmonary complications. There is at all times a possibility of accidents even in the most hopeful cases. The plastic membrane may quickly extend upward into the trachea, or a capillary bronchitis may develop. Oppolzer and Fagge each report the fatal termination of a case through plugging up of the glottis or trachea by a large cast after it had become detached. Death has occurred before casts had been expectorated. The danger is always greatest in the extremes of life. And there is no means of prognosticating the course of the chronic form, its recurrences and remissions, for each case has its own peculiarities.

Treatment.—No uniform method of treatment has been adopted. Many remedies have been tried with more or less benefit, but it is difficult to estimate the results, since so few cases have come under the care of any one observer. Potassium iodide has been employed more extensively than any other medicine with a view to hastening the detachment of the fibrinous deposits. It has been given in large or small doses, alone or with the alkaline carbonates, but its effect has not been uniformly satisfactory. Ammonium chloride, ipecacuanha, senega, benzoic acid, apomorphine, and other expectorants have been recommended for the same purpose. Emetics may be employed in robust individuals to assist in the expulsion of the casts after they have become detached. Apomorphine administered hypodermically in the dose of gr. $\frac{1}{10}$ has given the best results. Mercurial inunctions are recommended by Eichhorst[24] and Strümpell, but are condemned by others, except in syphilitic cases. N. S. Davis, Sr.,[25] obtained prompt benefit from sodium salicylate in a rheumatic subject. In the writer's case prompt recovery followed the administration of creosote carbonate in fifteen-drop doses.[26] Steam and various medicaments have been recommended for use by inhalation, but it does not seem probable that any remedy can be applied to the smaller tubules by this method in sufficient quantity to be of real benefit. Stewart and Gibson[27] find steam of undoubted utility. Lime water and solutions of the alkaline salts, lactic acid, carbolic acid, or trypsin have been employed by atomization. Schnitzler suggests the employment of papayotin in this manner, and Ewart recommends the intratracheal injection of oil.

Every effort should be made to improve the general condition of the patient by such measures as are advisable in cases of chronic bronchitis. In this way only is there a hope of preventing future attacks. Residence in a dry, bracing, atmosphere (Oliver[28]), proper clothing, good food, exercise especially directed to the development of the respiratory muscles, proper bathing, with the administration of the bitter tonics, arsenic, iron, and malt preparations, or cod-liver oil, are worthy of trial. In many cases the treatment of the underlying condition must to a great extent take precedence over that of the disease itself.

James M. French.

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FIBROMA.—Definition; Synonyms; General Characteristics.—A fibroma is a tumor composed of fibrous connective tissue, *i.e.*, of cells, fibrillæ, and vessels. It is known also under the name of fibroid, desmoid, and, in certain positions, polypus. The term "fibroma" is applicable only to circumscribed new growths of connective tissue, and does not include the diffuse connective-tissue hyperplasia seen in elephantiasis, nor the connective-tissue stroma entering into the composition of other sorts of tumor. In this connection it is to be observed that the application of the term "fibroid" to the common tumor of the uterus is incorrect, since this tumor consists primarily of smooth muscle, and is therefore a myoma. The fibroma is a member of the connective-tissue or histoid group of tumors, and is co-ordinate with the lipoma, the chondroma, the myoma, etc. It is non-malignant, although not always sharply to be distinguished from certain forms of sarcoma. It is widely distributed, and may occur in any part of the body containing fibrous connective tissue.

General Morphology. Varieties.—Fibromata occur as rounded, sometimes lobulated, masses, often sharply circumscribed, and varying in size from a few millimetres to many centimetres in diameter. One variety of this form of tumor, the keloid, presents a more diffuse and less circumscribed character than is typical of the fibromata as a class. Fibromata originating in the subcutaneous and in the submucous tissues may present a papillary form and constitute certain sorts of so-called papillomata and polypi. According to their consistence and in a measure to their histological structure, fibromata present two general morphological types: (1) Hard; (2) soft.

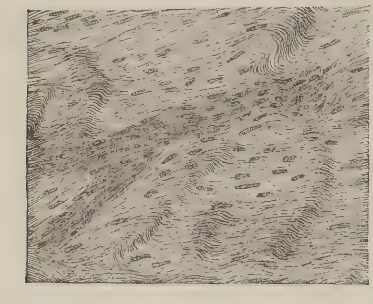

FIG. 2094.—Section of a Fibroma of the Ovary. (From Councilman.) The tumor is dense and compact; the cells are few in number; in several places on the section bands are seen in which the cells are more abundant. × 75.

I. HARD FIBROMA (F. durum.).—(*a*) *Anatomical Characteristics.*—This type occurs usually as a mass varying in size from that of a pin's head to that of a cannon ball, the smaller tumors rounded, the larger often lobulated; sometimes encapsulated; of white or pink color, and of very firm, tough consistence. Upon section the tumor creaks under the knife, and presents a dry, white or grayish-white, rather refractive surface, marked by striæ traversing it in various directions, sometimes forming concentric lamellæ or whorls. The surface of section in some cases presents a small amount of fluid resembling that found in synovial cavities, or is marked by red points corresponding to divided blood-vessels. The physical properties of the tumor may be uniform throughout its entire extent, or may vary in different localities.

(*b*) *Histological Characteristics.*—The constituents of this type of fibroma are analogous to those composing the dense fibrous connective tissue of the tendons, the fasciæ, and the periosteum. They consist essentially of connective-tissue cells, variable in number, but usually few, and fibrillæ closely compacted and running in various directions. The cells ("connective-tissue corpuscles") possess but little protoplasm and are recognizable chiefly by means of their nuclei, which are rather small, deeply stained, and spindle- or rod-shaped, sometimes curved; when cut transversely, the nuclei appear round. In a fibroma which is growing rapidly the cells are relatively numerous, large, and rich in protoplasm. The number of the cells is of no special significance, provided that they present the characteristics of the normal connective-tissue cell. The fibrillæ (intercellular substance) occur in compact, more or less wavy, refractive bundles between which may be seen the nuclei of the cells. In some instances the fibrillæ are indistinct and appear to be merged into homogeneous lamellæ. Besides the ordinary fibrillæ, the intercellular substance may include a variable amount of elastic fibre. In addition to these histological elements, the hard fibroma presents blood-vessels and a variable number of leucocytes and of lymphoid cells, the last named occurring usually in the form of perivascular groups which may be regarded as small lymph nodules (Ribbert). The blood-vessels vary both in number and in size; ordinarily they are few and poorly developed. In occasional instances the veins are of abnormally large size (F. telangiectaticum, F. cavernosum; angio-fibroma).

According to their situation, hard fibromata may embrace yet other constituents, and thereby present a more complex structure than that which is characteristic of simple fibroma, and one which in some instances warrants the classing of the tumor with other sorts of new growth. Thus fibromata arising from epithelial structures and from nerves, or occurring in their vicinity, by including such structures within them, may acquire special and distinctive characteristics (adeno-fibroma; neuro-fibroma; papilloma). Again, the development of fibromata from periosteum and from perichondrium may result in the presence, in such tumors, of bone or of cartilage (*vide infra*).

II. SOFT FIBROMA (F. molle; F. areolare).—(*a*) *Anatomical Characteristics.*—The soft fibromata occur as circumscribed, round, or lobulated masses, often of very large size, of a pale yellow color, and of soft, inelastic consistence. Upon section, they present a slightly transparent, grayish-white surface, showing a fine meshwork of fibres, sometimes large cystic spaces, filled with a variable amount of clear, watery fluid which flows freely from the cut surface, and allows the tumor to collapse. Occasionally the surface of section is traversed by broad, fibrous bands running in various directions.

(*b*) *Histological Characteristics.*—The structural elements of this form of fibroma correspond to those seen in the areolar type of fibrous connective tissue. They consist essentially of cells and fibrillar intercellular substance. The cells in general are of the type common to mature connective tissue. Together with these are larger, round, oval, or stellate cells. As in the hard fibroma, nodules of lymphoid cells are frequently present. The intercellular substance is relatively scanty, and the fibrillæ are delicate and arranged in small bundles. Elastic fibres occur frequently, and in some cases are so abundant as to form a large part of the tumor. The fluid content of the tumor upon microscopic examination presents but few cellular elements, and therein differs distinctly from the opaque, milky fluid, rich in cells, which may be expressed from malignant, highly cellular tumors.

The distinction between these two types of fibroma is not absolute; every gradation between the hard and the soft varieties occurs, and not infrequently both sorts are represented in the same tumor.

III. KELOID.—Included amongst the fibromata is a connective-tissue new growth of somewhat variable character and known by the name of keloid (cheloid). It differs from other fibromata in manifesting a less circumscribed mode of growth, in presenting a close resemblance to scar tissue, and in being devoid of elastic tissue (Aschoff). The keloid develops in the corium of the skin as a dense mass of connective tissue often of considerable size, situated usually just beneath the epidermis and smoothly covered by it. It may remain as a scar-like band, or by its weight become flattened and polypoid. The growth is not always sharply defined, and may not seem to possess the physical properties of a tumor. Histologically the keloid consists of dense fibrous connective tissue closely resembling scar tissue and containing thick, refractive bundles of fibrillæ. In its earlier stages of development, or when growing rapidly, the tumor is very cellular. It often is connected with underlying parts by fibrous prolongations, which render its complete extirpation difficult. Two types of keloid may be recognized, according to the origin of the tumor: (*a*) Cicatricial; (*b*) spontaneous.

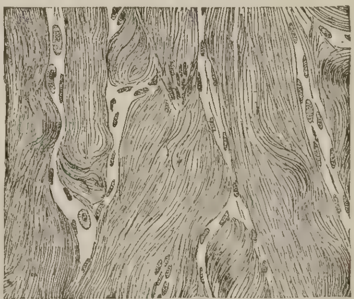

FIG. 2095.—Section of a Spontaneous Keloid from the Ear of a Young Negro. (From Councilman.) × 75.

(*a*) The *cicatricial keloid* occurs after injuries to the skin as an hypertrophy of the resulting scar, with more or less tendency to recurrence after removal. This form of keloid is more apt to develop in the scar following burns than in that consequent upon other sorts of injury. It is said to be more common in tuberculous and in syphilitic subjects than in others. Keloids developed from cicatricial tissue resulting from an infected wound of the skin may be transitory (Aschoff).

(*b*) The *spontaneous keloid* ("true keloid") occurs independently of trauma. It consists of dense connective tissue. Like the cicatricial keloid, and owing to the difficulty of complete extirpation, it possesses a marked tendency to recurrence. It appears most often in persons who live in tropical climates, and gives rise to intense itching in stormy weather.

MODE OF GROWTH.—Fibromata, from the fact of their dense consistence and relative paucity in cells, in the course of their development present no tendency to invade surrounding structures nor to produce metastases, and are thus essentially benign tumors. Increase in size is by central growth; surrounding structures either are pushed aside or undergo atrophy. In many instances the fibroma is enclosed by a capsule composed of dense tissue, which separates it sharply from surrounding structures. Others are less sharply defined, and bands of fibrous connective tissue pass from the tumor into adjoining parts; this may be true even of the pedunculated forms. The total extirpation of such a tumor is difficult and at times almost impossible. This fact probably accounts for the recurrence of fibromata in certain instances after operation. Leucke states it as a general rule that when operation for removal is complete there will be no recurrence. In other instances, supposed fibroma may have been a fibro-sarcoma. Virchow mentions a case, however, in which a large primary fibroma of the uterus was associated with metastatic secondary tumors in the mesentery and the omentum. There seems to be no tumor which under certain circumstances may not become malignant.

The course of development of the fibroma is slow but continuous, and the size to which it may attain indefinitely great. The direction of growth is always in that of least resistance, but in certain positions fibromata may exert considerable pressure and thereby injure surrounding parts. Fibromata developed in the skin and in the mucous membranes, if of sufficient size, may push upward, carrying the covering epithelium before them, and so give rise to warty or papillary tumors sometimes pedunculated and polypoid.

OCCURRENCE.—SPECIAL MORPHOLOGY.—The occurrence of fibromata is not associated with any special locality, but tumors of this class may originate in any part of the body which contains fibrous connective tissue. They develop most frequently from the skin, the subcutaneous tissue, the periosteum, the intermuscular septa, the submucosa of certain mucous membranes, and the nerve sheaths; also from the serous membranes, the retroperitoneal tissue, the perichondrium, and from the connective-tissue stroma of such organs as the breast, the kidney, the spleen, the ovary, and the uterus. The tumor presents distinctive morphological characteristics dependent upon its locus of occurrence.

1. *Skin.*—The skin is very commonly the seat of fibromata. They here may be of either variety, but are usually of the soft type; may originate either in the corium or in the subcutaneous tissue; and are often multiple. The multiple fibromata do not possess genetic unity, but may arise in various ways. The more common form of fibroma of the skin, and one frequently multiple, is that designated by Virchow as

(*a*) *Fibroma molluscum.* This develops from the subcutaneous areolar tissue of the face or of the back, sometimes of the entire body, as a rounded, dependent, often pedunculated outgrowth, at times no larger than a pea, often attaining an enormous size, and presenting a soft, almost fluctuant consistence. The tumor is sometimes broad, and when pendulous from its weight is attached to the body by a wide fold of skin. Such a tumor is known as *cutis pendula.* Histologically, this sort of fibroma is rich in cellular elements, many of which are spindle-shaped. Another mode of occurrence, in the skin, of multiple fibromata is seen in

(*b*) *Neuro-fibroma.* This form of tumor presents itself in the form of multiple, hard, spindle-shaped masses varying in size from that of a small pea to that of a walnut, and distributed along the course of a single nerve, or of all the nerves of an extremity or even the whole body. They originate from the connective tissue of the nerve sheaths, and usually contain within their substance a certain number of nerve fibres included by the tumor in the course of its development.

(*c*) *Multiple fibromata* of the skin of the hard type have been shown (von Recklinghausen) to originate also from the connective-tissue sheaths surrounding the sebaceous glands, the sweat glands, the hair follicles, and the vessels of the corium.

2. *Mucous Membranes.*—Fibromata of the mucous membranes develop from the submucous tissues, appear in the form of polypi, and are often multiple (Ribbert). In the nares they occur as soft, pedunculated, often œdematous masses, constituting one of the varieties of nasal polyp. In the larynx fibromata are common, and appear as polypi situated usually upon the vocal chords or in the fossa of Morgagni; the tumor may be of the hard type, originating from the perichondrium. Fibromata sometimes occur in the alimentary tract, especially in the large intestine.

3. *Periosteum.*—Periosteal fibromata are frequent; they contain not infrequently bone, which in amount may exceed that of the fibrous connective-tissue elements; and they present the appearance of firm, hard masses easily mistaken for either chrondroma or osteoma. An important example of periosteal fibroma is seen in one of the varieties of nasal polyp, viz., that occurring in the nasopharynx. The tumor here originates from the periosteum of the base of the skull, extends downward and laterally into the pharynx, and forward into the nares, and is remarkable for the destructive energy of its growth, which may suffice to force apart the bones of the face, giving rise to the characteristic "frog-face." It is usually lobulated. Histologically, it is characterized by a dense fibrous structure, although at times large vessels are present, and in other instances the cells are relatively numerous and indicate by their protoplasmic character rapidity of growth. The vascular character of certain of these tumors renders considerable the hemorrhage incidental to their removal. The naso-pharyngeal polypi contain as a rare constituent occasional islands of cartilage. Periosteal fibromata not infrequently occur as small masses upon the maxillæ of old people.

4. *Parenchymatous Organs.*—In the mammary gland the fibroma appears as a firm, circumscribed, encapsulated tumor, which may be multiple; and also as a more diffuse growth; the latter can with difficulty be differentiated from the fibrous induration consequent upon chronic inflammation. The fibroma of the breast frequently originates in the periglandular connective tissue; in this case there is usually associated hyperplasia of glands. Pressure exerted by the tumor upon the glands and their ducts may lead to cystic dilatation, and into the resulting spaces papillary projections of the tumor may extend, carrying upon their surface the glandular epithelium. Certain of these projections may grow for a considerable distance into the lumina of the glands and of their ducts, giving rise to variable and complicated histological appearances. Anatomically, such a tumor upon section presents clefts or irregular fissures, with occasional small cysts containing clear, viscid fluid. When the cyst formation is extensive, the major part of the tumor may project into the cavity, and upon section appear as a large, irregular polypus. This form of tumor belongs to the class of adeno-fibroma.

In the kidney a curious form of fibroma is met with. It appears as a pearly white, firm nodule, situated usually near the base of a pyramid, and histologically presents the characteristics of a circumscribed interstitial nephritis.

RETROGRADE METAMORPHOSES.—Retrograde changes of every variety occur in the fibroma, usually after prolonged duration of the tumor.

1. *Mucoid degeneration* is the more frequent, and is characterized by the formation of large cysts containing thick, viscid fluid. The process begins with an increase in the cellular constituents of the tumor, associated with a mucoid degeneration of the intercellular substance which thereby undergoes softening and is reduced to a fluid state. The cells in the degenerated area then disappear, the resulting space being occupied by the fluid. This degeneration may readily be confused with

2. *Œdematous infiltration*, a condition due to disturbances of circulation within the tumor; here the ground substance of the growth becomes soaked with fluid, the fibrillæ are pressed apart, and the tumor becomes soft and spongy, upon section presenting the appearances seen in gelatinous infiltration of the skin or in the umbilical cord.

3. *Fatty degeneration* occurs infrequently in the central part of the larger fibromata; the region involved becomes yellow, soft, and ultimately may be converted into a cavity filled with fatty detritus. Such an area of softening, if it extend to the surface of a fibroma situated near a free surface, may lead to ulceration.

4. *Calcification* is sometimes seen, at first in small and circumscribed areas, latterly in perhaps a large part of the tumor. The capsule of the tumor may be in great part calcified.

5. *Ossification* is common in fibromata developed from the periosteum, and occasional in those originating elsewhere.

COMBINATION WITH OTHER TUMORS.—The fibroma is frequently in combination with other members of the connective-tissue group of tumors. It is most often seen in association with *sarcoma* in the form of a tumor parts of which are made up exclusively of spindle cells and parts of fibrous connective tissue, with elsewhere intermediate gradations; such a tumor is known as a *fibrosarcoma*. Another combination often met with is the *myxo-fibroma*, which is a more common tumor than simple fibroma; here, in addition to fibrous connective tissue, the tumor contains myxomatous tissue consisting of branched and stellate cells embedded in a mucoid matrix. Association of fibroma with *hæmangioma* is seen in fibrous connective-tissue tumors containing large, intercommunicating venous sinuses; and with *lymphangioma* in such tumors of that class as show marked development of their connective-tissue elements. Combination with *myoma* is seen in the common tumor of the uterus; connective-tissue formation is here usually subsequent to the hyaline degeneration of portions of the primary constituents of the tumor. (For Neuro-fibroma, see *Neuroma*.)

ETIOLOGY.—Fibromata may develop at any time of life, and are sometimes congenital; they occur more frequently after the twentieth year than during childhood, but are not common in old age. The fibromata of the breast, like myomata of the uterus, occur most frequently between the thirtieth and the fortieth years; they are as common in nulliparous women as in those who have borne children.

As to the cause of this class of tumors there is little to be said. Irritation is often supposed to stand in causal relation with the origin of fibromata, but there are no better grounds for regarding mechanical injury as a factor in the development of this than of any other tumor. One of the forms of keloid, the cicatricial, is consequent upon injury to the skin, but that fact does not explain why the scar tissue in which it develops should become hyperplastic. It is possible that a predisposition to tumor formation may in this case exist in the skin, which becomes manifest as a weakening of the physiological resistance of the surrounding tissues toward the growing reparative tissue, or in a tendency on the part of the connective tissue to assume this special mode of growth. There is some evidence of a family predisposition to keloid formation (Aschoff).

DIAGNOSIS. — CLINICAL SIGNIFICANCE.—The clinical diagnosis of fibroma in a majority of instances presents little difficulty. The hard fibroma offers distinguishing characteristics in its circumscribed form and in its dense and homogeneous consistence. From the *sarcomata* as a class it may be differentiated by its relatively slow rate of growth. From *scirrhous carcinoma* it is usually distinguishable, save in those instances in which the fibroma is so situated as to cause pressure, by the absence of pain, by the mobility of the tumor, and by freedom from involvement of overlying skin. The differentiation of hard fibroma from *fibrous induration* of glands offers more difficulty, and is often attended with error. In such cases an important aid to diagnosis lies in the clinical history of a previous inflammatory process. The soft fibromata, or such of the hard type as have undergone degeneration with subsequent softening, may easily be mistaken for *lipomata* or for *cysts*.

Histological diagnosis offers little difficulty save when the tumor presents an appearance intermediate between fibroma and sarcoma, or when there is a question of fibroid induration, or of scirrhous carcinoma containing but few epithelial elements.

The clinical significance of the fibroma is comparatively slight. An essentially benign tumor, it is harmful only when its position is such as to result in pressure upon surrounding and possibly vital parts, or in the obstruction of important natural canals. Fibromata of the skin, from their exposed situation, are liable to trauma, and if injured may become the seat of ulceration.

George Burgess Magrath.

FIG.—FICUS. "The fleshy receptacle of *Ficus Carica* L. (fam. *Moraceæ*) bearing fruit upon its inner surface" (U. S. P.). This fruit can scarcely be regarded as a medicinal substance, though nutrient, and, like most sugary fruits, slightly laxative. It is retained in the Pharmacopœia merely because of its entering into the *Confectio Sennæ*, but it seems likely that both it and the latter little-used remedy will shortly be dropped. Figs are commonly combined with purgatives. One method is to turn them inside out and stuff them with senna leaves, the mass being then chewed and swallowed. Figs grow upon a large shrub or small tree, natives of the Orient, but cultivated in all warm countries, being hardy, with slight protection, as far north as Philadelphia. The dried fruit consists of nearly two-thirds its weight of sugar, some fat and gum, and small amounts of laxative salts. It is decidedly nutritious and has been known, in the fresh state, to constitute the chief food of armies for short periods. Besides the varieties distinguished by the names of the places from which they are exported, as Smyrna, Turkey, Greek, Marseilles, etc., figs are imported in two forms, known as "pulled" and natural. The former are rolled and kneaded until their structure is broken up and they have become soft and pliable; the solidly packed, layered, flattened figs are of this sort: the others are simply dried in the natural condition. These are oblong, rounded, and longitudinally wrinkled. *Henry H. Rusby.*

FIGWORT. See *Scrophulariaceæ.*

FILARIA MEDINENSIS; FILARIA SANGUINIS HOMINIS. See *Nematodes.*

FILMOGEN (Liquor adhæsivus) is a solution of soluble cellulose nitrate in acetone, with the addition of a little castor oil. It is transparent, adhesive, and impervious to water, and resembles flexible collodion in its appearance and uses. *W. A. Bastedo.*

FISSION.—(L. *fissio*, a cleaving, from *findere*, to split.) Fission is a process of multiplication in which the parent organism divides into two daughter organisms approximately equal in size and development; as distinguished from budding, in which the parent remains intact and the daughter organism is a new individual formed by a small outgrowth upon the parent. (See article *Budding.*)

Ordinary cell division is a process of fission, and, consequently, this is the usual method of reproduction among the unicellular organisms. The yeasts and some of the Protozoa, however, reproduce by a process more accurately described as budding. But the Bacteria, Protophyta, and nearly all of the Protozoa mutiply by fission and often with almost incredible rapidity. In the simpler forms there are no preparatory changes other than those ordinarily associated with cell division in these groups. But in the more highly differentiated Infusoria provided with permanent oral funnels, ciliated bands, etc., these structures may be duplicated in the two new individuals previous to their separation, a process analogous to what takes place in many multicellular organisms.

The multiplication of individuals by fission is unknown among plants above the very simple Schizophyta.

Among the Metazoa, on the other hand, this method of multiplication is common in some of the lower orders and may occur abnormally in so high a group as the vertebrates.

In a few cases fission occurs without any previous preparation. The adult animal tears its body apart by its own efforts. A wound is formed by the rupture of the tissues with a loss of the fluids of the body. This wound heals, and from its surface the missing parts of each of the new individuals are regenerated. The method has been observed in the genus Hydra, in two annelids, Lumbriculus and Ctenodrilus, and in certain star-fishes and ophiurans. In the latter the plane of fission passes through the disc dividing the mouth and the stomach, while to one part of the disc three arms remain attached, to the other, two; and each half regenerates the missing parts. But in one family of star-fishes, the Linckiidæ, the process is somewhat different. Here the five arms separate from the disc and then the disc regenerates five new arms, and each detached arm regenerates a disc and four new arms. Delage relates that he observed once the division of a sea anemone, *Anthea cereus*. The two parts of the body were extended as if trying to crawl in opposite directions. The intermediate portion became much constricted and finally ruptured. The whole operation occupied about two hours.

On the other hand, in most animals in which fission is a normal process of multiplication, it is preceded by preparatory changes which result in each of the new individuals being provided with a full complement of organs before separation takes place.

According to Parker, fission in the common sea anemone of the coast of New England, *Metridium marginatum*, is a slow process occupying many months. It begins with the division of the mouth and oral disc accompanied by the formation of new septa, and proceeds gradually toward the base. The final separation has not been observed, however.

In many worms fission takes place in what may be regarded as a larval stage, before the development of eggs and spermatozoa. This, according to Mensch, is the case with Autolytus, and it seems to be so with most of the worms in which fission occurs. In Antolotus and its allies an area of embryonic tissue appears at about the thirtieth segment, dividing the young worm into two parts. On the posterior part there is developed a new head. The tissues just in front of the head undergo degeneration, and by their own movements the two individuals are broken apart.

Among the jelly-fish of the group Scyphomedusæ fission is associated with the metamorphosis from the larval to the adult form. In Cassiopea, for example, the scyphistoma larva is a graceful little creature shaped like a wine glass and lives attached by its base to some solid body. When fully developed this larva becomes divided into two portions by a horizontal constriction. It is then called a strobila. The upper part of the strobila becomes transformed into a medusa, while new larval tentacles and the rudiment of a proboscis are developed on the lower part. Finally the narrow isthmus connecting these two parts undergoes degeneration and is at length ruptured by the violent swimming movements of the young medusa.

Fission may take place in an early embryonic stage of development. According to Kleinenberg this occurs normally in one of the earth worms, *Lumbricus trapezoides*, in which the embryo divides into two shortly after the gastrula stage and both develop into normal individuals. This has been observed to occur under abnormal conditions in the trout and the chick. If hen's eggs be incubated at a temperature slightly above normal a large proportion of the embryos will be found to show a tendency to the formation of double monsters and occasionally the area embryonalis will be found to contain two distinct embryos. A similar division of the embryo may occur in man. If incomplete, it will give rise to a double monster or to such cases as the Siamese twins and Millie-Christine. If the separation be complete the result will be a pair of twins of the same sex. In every case of fission all the individuals produced from a single ovum are of like sex.

In some of the lower forms of animal life fission may be normally incomplete, as in some corals, in which the individuals remain in organic union forming a colony, or cormus.

There are some animals in which a form of fission occurs in the fully mature adult, which does not serve to multiply the individual but for a more favorable dispersal of the sexual products. The formation of proglottides by the common tapeworm is an example. Another example is the palolo worm of Samoa, an annelid that burrows in the coral rock. When mature the posterior portion of the body, distended with eggs or spermatozoa, is separated off and swims on the surface of the water, where the sexual products are discharged. They occur at certain times in great abundance and are gathered by the natives, who relish them greatly as an article of food.

The relation between fission and budding is a very close one, so much so that Bock has argued that they are simply two forms of one fundamental process. In many sea anemones, for example, small fragments of the foot become detached and subsequently develop a mouth and tentacles and become complete individuals. Such cases make it difficult to draw a sharp line between fission and budding. In forms like Autolytus, mentioned above, the two processes are closely associated. For, after the original posterior part of the body is separated off, the embryonic area on the end of the anterior portion, or parent stock, may give rise to any number of new individuals by a continuous process of budding. Nevertheless in most cases the distinction between fission and budding is a clear one and is useful in practice.

Robert Payne Bigelow.

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FIXED OILS. See *Active Constituents of Plants.*

FLAG, BLUE.—IRIS. "The rhizome and roots of *Iris versicolor* L. (fam. *Iridaceæ*)" (U. S. P). This is a very common swamp plant of eastern North America, erect, about two or three feet high, with sword-shaped, equitant leaves and handsome blue flowers, marked in the centre with white and yellow stripes.

Rhizome of horizontal growth, branched, the branches 5 to 10 cm. (2 to 4 in.) long and 1 to 2 cm. (⅖ to ⅘ in.) thick, cylindrical in the lower half, thence becoming vertically flattened toward the crown, where it is terminated by a circular scar; dark brown, wrinkled, annulate with the leaf-bases; fracture short, purplish; roots long, slender, simple, crowded near the flattened end; odor peculiar; taste pungent, acrid, and nauseous.

This drug was in use by the aborigines, and has been employed to a moderate extent by physicians for many years. The uncertainty and harshness of its action have, however, prevented its becoming a favorite. An acrid resin, fixed oil, tannin, gum, starch, etc., are given as its constituents.

It belongs to the resinous class of cathartics. When quite fresh, it is an irritant-emetico-cathartic, easily acting as a poison in over-doses. Upon drying and keeping, these harsh actions are continuously ameliorated, and after a year or more it becomes a reliable purgative, not excessively harsh if given properly diluted and with the drug well distributed through the excipient. It then ranks with jalap, leptandra, and similar drugs.

Dose of the powder, from 0.5 to 1.5 gm. An extract (*Extractum Iridis*), dose gr. i. to iij., and a fluid extract (*Extractum Iridis Fluidum*), dose ♏ x. to xxx., are official. A precipitated extract, "Irisin" or "Iridin," is in rather common use. *Henry H. Rusby.*

FLAG, SWEET. See *Calamus.*

FLEABANE.—ERIGERON. Several species of the large genus *Erigeron* L. (fam. *Compositæ*) have been official and largely used in medicine. Because of their inferiority, they gradually disappeared from use, with the exception of one, known as *E. Canadense* L. Botanists now accord this generic distinction from the others. It is known as *Canada Fleabane, Colts-tail, Pride-weed, Bitter-weed,* Blood-staunch, etc., the leaves and flowering tops of *Leptilon Canadense* (L.) Britton. The plant is a very tall and robust annual weed, exceedingly common and abundant in the eastern United States and Canada, and widely distributed over the entire world, in tropical as well as temperate regions. The hairy stem is from two to eight feet high, erect, slender, simple up to the inflorescence and densely clothed with ascending or nearly erect lanceolate leaves, from three to six inches in length. Above this the tawny, fluffy paniculate inflorescence strongly suggests the appearance of a colt's tail and gives the name. The drug contains much tannin, about one per cent. of the volatile oil next considered, and an amaroid. It is not remarkable that this should be one of the most valuable of all household remedies for controlling severe attacks of serous diarrhœa, as its oil powerfully stimulates the sympathetic abdominal nerves, while its tannin astringes locally. It is at the same time a good aromatic bitter. The country practice of giving it in infusion, in doses of ʒ ss.–i., is improved upon by giving 2 to 4 c.c. (fl. ʒ ss.–i.) of the fluid extract.

Henry H. Rusby.

FLEABANE, OIL OF.—OIL OF ERIGERON. OLEUM ERIGERONTIS (U. S. P.). A volatile oil distilled from the last, of a pale-yellow or brownish color, a peculiar, pleasant odor, and a warm, pungent taste. It has a spec. grav. of about 0.850, increasing with age to about 0.890, and consists chiefly of dextrogyrate limonene. It is quite a different substance as distilled, even when fresh, from what it is in the plant, as there is a portion which is destroyed by even a moderate heat. This fact, together with the absence of the other constituents of the herb, indicates the error of substituting the latter by the oil. The oil is, however, active. It belongs to the astringent class of volatile oils, acting like oil of turpentine in this respect, but without its irritating properties. It is administered for the same purposes as fleabane, and for the control of hemorrhages of the bowels and uterus, and for gonorrhœa. The dose is 0.3 to 1 (♏v. to xv.).

Henry H. Rusby.

FLORIDA.—Twenty years or more ago Florida was perhaps the most popular winter resort in this country for the consumptive. He was sent there in all stages of the disease, especially in the more advanced ones. It was the final resource when all else failed, and, in the majority of cases, proved to be an illusive one.

At the present day it is rare that the phthisio-therapeutist directs his consumptive patient to this region, although possessing a winter climate unexcelled in many of its characteristics by any region east of the Rocky Mountains. Why is this? In a word, it is because we now have a truer conception of the limitations of climate, in its application to pulmonary tuberculosis. The hygienic-dietetic treatment is the authoritative one, established on the firm foundation of experience; and in the execution of this treatment climate is but one factor, and perhaps not the most essential one. Formerly climate was supposed to be the great determining element in the treatment and all else was merely accessory; and further, a warm climate was considered to possess peculiar advantages for the consumptive.

It is natural that such should have been the idea entertained with the knowledge of the pathology of the disease then obtaining, and before the results of Brehmer and other German pioneers in the sanatorium treatment had become known or had indeed been determined. What more natural than that a consumptive depressed in mind and body should look to a warm, sunny, equable climate, with its semi-tropical attractions, as the El Dorado from whence he should receive renewed hope and health? Although Florida will continue to be a great and a popular health resort for many functional and organic diseases, and for the valetudinarian in general, as will be more fully discussed later, it will still also, in the writer's opinion, offer certain locations which possess the essential climatic conditions for the successful accomplishment of the hygienic-dietetic treatment of tuberculosis. If situated on the more elevated portions in the central part of the peninsula, it would seem that sanatoria would justify their existence. Or even if they are situated upon the coast at one side or the other, they should serve a good purpose, for at these points there surely would be pure air, an abundance of sunshine, and an equable temperature, with a freedom from high winds. The objections are the enervating character of a warm climate of this nature,—a climate that increases the anæmia usually found in phthisical patients, as Solly has observed,—and also the possibility of malaria, which is present in some of the resorts at certain seasons of the year, and to the influences of which the consumptive with his depressed vitality is peculiarly susceptible.

Such places as Winter Park, Orlando, Altamonte in the interior, and Tampa, Los Pinellas, and the Lake Worth district on the coast, would seem to be favorable for the experiment of the genuine open-air treatment of consumption.

As with all tropical or semi-tropical countries, however, the summer climate of Florida would hardly admit of a continuous residence, which is, in many cases at least, important if the best results are to be obtained, although in Southern Florida the difference between the summer and winter temperatures is comparatively slight. The rainfall, however, in the summer months is considerably higher.

The State of Florida may be described as consisting of a continental portion, immediately contiguous to the States of Georgia and Alabama,—its southwestern portion washed by the Gulf of Mexico,—and a peninsula portion washed by the Atlantic Ocean and Gulf of Mexico. Keating (Transactions of the American Climatological Association, 1885) divides Florida geographically into a north and a south portion, the boundary line being the 29th degree of latitude, and topographically into the lowlands on the rivers and coasts, and the interior highlands, with an altitude of from 100 to 300 feet. Below the 29th parallel, the climate, both in summer and in winter, differs from that of the region north. The cold northwest winds are tempered by the warm waters of the Gulf of Mexico, which prevent the sudden changes of temperature that sometimes occur in the northern portion. In summer the sea breezes from both sides of the peninsula temper the heat and the nights are generally cool (Solly).

The land (except the interior highlands before mentioned) is for the most part low, and there are many lakes, streams, and salt-water channels. The principal river is the St. John's, running north, and navigable for large steamers a distance of 198 miles to Enterprise, and for smaller ones about 70 miles further up the river, to Salt Lake. The soil is "as a rule sandy, very porous in hilly or undulating sections, but finer and more compact on level reaches. The character of the subsoil hard-pan varies greatly in different localities, being sometimes clay and sometimes lime rock, at variable depths of from only a few to ten or more feet from the surface" (J. P. Wall, in the *Climatologist*, October 15th, 1891).

The varieties of land are the pine land in the highlands, high hummock, low hummock, savanna, and swamp. "The pine-land regions are those in which the sandy soil predominates, and, for the residence of invalids, places possessing such sandy soil appear to be the most healthful" (Richards).

The climate is a mild, moist, warm one, with a goodly number of sunny days. The principal season begins in January and lasts until April, and thousands of visitors who desire for any reason to avoid the inclemency of a Northern winter and lead an outdoor life, frequent the numerous resorts. Enormous palatial hotels and many boarding houses and villas exist in various portions of the peninsula, at St. Augustine, Palm Beach, Tampa, Palatka, Altamonte, Magnolia, Enterprise, Titusville, and at many other places. The attractive spots where one may pleasantly spend the winter are almost innumerable. The outdoor attractions in this fascinating country are varied and numerous,—fishing, hunting, bathing, golf, sailing, riding, and all the many excursions by water, chief of which is the famous journey up the Ocklawaha River, where one passes through cypress forests with the graceful hanging moss, or through clusters of palm and palmetto trees, and all the varied vegetation of a tropical region. Alligators are frequently seen, and "birds of the most curious forms and brilliant plumage are everywhere conspicuous" (Appleton's "General Guide to the Southern States," 1899).

The orange groves are always a delight; and the cultivation of the many fruits, flowers, and vegetables which grow so luxuriantly in this climate render outdoor life on the land a constant source of pleasure and interest. "The sun shines so brightly, the air is so balmy, the songs of the birds are so enlivening, and the orange trees in their bloom, or laden with their golden fruit, lend such a charm to the outlook from the windows that the most indolent or most cold-blooded invalid feels little inclined to stay indoors" (Lente).

The climatic characteristics will now be considered somewhat in detail, and for this purpose the following meteorological tables have been arranged from the observations of the United States Weather Bureau.

AVERAGE TEMPERATURE.

	December.	January.	February.	March.	July.	Year.
Jacksonville......	55.8	55.8	58.1	62.7	82.5	69.2
Jupiter	67.2	63.4	66.7	68.8	80.5	73.4
Tampa	62.2	58.6	63.1	66.4	81.5	71.6
Punta Rassa......	64.5	64.7	66.2	68.6	81.3	73.4
Key West	70.1	70.3	71.8	73.6	84.0	77.5

AVERAGE DAILY RANGE.

	December.	January.	February.	March.	July.	Year.
Jacksonville......	17.0	16.7	16.4	17.4	16.1	
Jupiter...........	12.2	15.0	13.4	14.0	12.2	12.6
Tampa............	18.0	19.8	17.1	18.9	16.1	17.7
Punta Rassa	13.5	12.7	12.9	13.4	13.0	
Key West	8.1	8.9	8.9	9.4	12.5	

MEAN OF WARMEST TEMPERATURE.

Jacksonville	66.4	64.9	68.5	73.6	91.6	
Jupiter...........	73.3	70.9	73.4	75.9	86.6	79.7
Tampa	71.2	67.8	71.7	75.8	89.6	80.5
Punta Rassa......	71.9	71.3	73.2	76.1	88.9	
Key West	75.3	75.4	77.1	78.9	91.3	

MEAN OF COLDEST TEMPERATURE.

Jacksonville......	49.4	48.2	52.1	56.2	75.5	
Jupiter	61.1	55.9	60.0	61.9	74.4	67.1
Tampa	53.2	48.0	54.6	56.9	73.5	62.8
Punta Rassa......	58.4	58.6	60.3	62.7	75.9	
Key West	67.2	66.5	68.2	69.5	78.8	

HIGHEST OR MAXIMUM TEMPERATURE.

Jacksonville......	81.0	80.0	83.0	88.0	104.0	
Jupiter...........	82.0	80.0	84.7	85.5	91.0	93.0
Tampa	81.3	78.1	80.5	84.2	93.2	94.4
Punta Rassa......	82.5	81.5	84.0	85.0	93.0	
Key West	88.0	90.0	87.0	89.0	97.0	

LOWEST OR MINIMUM TEMPERATURE.

Jacksonville......	19.0	24.0	32.0	31.0	68.0	
Jupiter...........	41.0	38.5	39.8	44.8	69.1	32.7
Tampa	34.7	32.7	35.7	39.7	70.0	28.1
Punta Rassa......	34.0	33.0	43.0	38.0	67.5	
Key West	44.0	48.0	55.0	53.0	72.7	

AVERAGE RELATIVE HUMIDITY.

Jacksonville	73.7	74.6	70.6	65.4	71.8	72.0
Jupiter, 8 A.M....	83.7	84.7	84.0	80.0	81.5	82.0
Tampa	83.4	81.6	83.8	80.0	82.4	81.2
Punta Rassa......	75.3	77.6	75.3	72.1	75.7	74.9
Key West	78.7	79.7	76.6	70.5	70.3	73.9

AVERAGE PRECIPITATION IN INCHES.

Jacksonville......	2.89	3.28	3.45	3.13	5.18	54.68
Jupiter...........	2.88	3.43	2.72	2.59	5.35	62.14
Tampa	1.57	2.45	2.81	2.68	7.99	53.09
Punta Rassa......	1.28	2.36	1.72	1.20	7.22	43.54
Key West	1.84	2.32	1.84	0.66	4.27	40.88

PREVAILING DIRECTION OF WIND—FROM—

Jacksonville......	N. E.	N. E.	N. E.	N. W.	S. W.	N. E.
Jupiter...........	N. W.	N. W.	S.	S.	S. E.	S. E.
Tampa	N.	N.	N. E.	S. E.	E.	N. E.
Punta Rassa......	N. E.	N. E.	N. E.	N. E.	E.	N. E.
Key West	N. E.	N. E.	E.	E.	E.	E.

AVERAGE HOURLY VELOCITY OF WIND, IN MILES.

Jacksonville......	6.0	5.8	6.9	7.9	6.3	6.7
Jupiter	10.2	9.9	10.7	10.6	7.6	9.7
Tampa	6.0	6.0	6.9	6.7	5.2	6.1
Punta Rassa......	10.3	10.2	10.7	12.0	8.2	10.1
Key West	11.2	10.8	10.4	11.2	7.5	9.7

AVERAGE NUMBER OF CLEAR DAYS.

	December.	January.	February.	March.	July.	Year.
Jacksonville	10.2	9.0	9.7	12.7	10.2	123.2
Jupiter	9.8	13.0	11.0	17.4	12.5	131.4
Tampa	12.1	9.5	8.4	11.7	7.0	115.0
Punta Rassa	12.1	9.8	11.5	14.7	3.4	102.9
Key West	11.0	11.3	11.7	15.8	5.7	113.4

AVERAGE NUMBER OF FAIR DAYS.

Jacksonville	12.0	12.8	10.4	13.0	16.0	156.7
Jupiter	14.1	11.0	11.1	9.7	13.4	153.8
Tampa	12.3	16.4	14.3	14.4	20.0	188.2
Punta Rassa	12.8	15.0	11.4	11.8	10.4	186.1
Key West	15.5	14.7	12.6	12.5	19.8	192.5

AVERAGE NUMBER CLEAR AND FAIR DAYS.

Jacksonville	22.2	21.8	20.1	15.7	26.2	279.9
Jupiter	23.9	24.0	22.1	27.1	25.9	285.2
Tampa	24.4	25.9	22.7	26.1	27.0	303.2
Punta Rassa	24.9	24.8	22.9	26.5	23.8	289.0
Key West	26.5	26.0	24.3	28.3	25.5	305.9

Five points are taken in various portions of the State to illustrate the different climatic factors: Jacksonville, on the St. John's River, about thirty miles from the Atlantic; Jupiter, on the Atlantic Coast, seventeen miles north of Palm Beach; Tampa, about twenty-five miles from the Gulf Coast, and about half-way down the peninsula; Punta Rassa on the Gulf Coast, almost opposite Palm Beach; and Key West at the extreme south, an island about sixty miles from the mainland.

In observing these climatic features the distinguishing characteristics are mildness and uniformity. It will be seen that the diurnal range for the coast stations is small, while that of Jacksonville and Tampa, further inland, is considerably greater, and least of all, as we should expect from its insular position, is that of Key West.

From the table of maximum and minimum temperatures it will be observed that for the four months from December to March inclusive the maximum ranges from 78.1° to 88° F., and the minimum from 19° to 44.8° F.; Key West excepted. "There is a possibility then of frost, snow and ice, although these phenomena are rare: they are the infrequent 'chances,' and occasionally a cold wave sweeps over the whole State, damaging or killing the orange trees, demanding fires indoors and winter clothing out." The relative humidity is high, characteristic of a marine climate, as this is: it is quite uniform throughout the year. "Of course, as might naturally be expected of a climate with the temperature and humidity of that of Florida, heavy dews in clear still nights are always present; and during the winter and spring fogs in the night and early morning are not uncommon. Fogs are, however, somewhat worse on the Atlantic Coast and along the St. John's River than on the Gulf side of the peninsula" ("The Climate of Florida," Dr. J. P. Wall, the *Climatologist*, November 15th, 1891). The mean annual rainfall may perhaps be considered high for a health resort, although about half occurs in the summer. For comparison the mean annual rainfall of various resorts is here given:

	Inches.		Inches.
Jacksonville, Fla	54.6	Aiken, S. C	48.0
Jupiter, Fla	62.1	Thomasville, Ga	51.5
Tampa, Fla	53.0	Augusta, Ga	44.0
Punta Rassa, Fla	43.5	San Diego, Cal	10.0
Key West, Fla	40.8	Los Angeles, Cal	18.0
Redlands, Cal	15.0	Santa Barbara, Cal	18.0
Denver, Col	14.4	Cannes, France	25.0
Nice, France	32.0	Cairo, Egypt	15.0
New York, N. Y	42.5		

The prevailing winds are from the east, bringing the pure air from the Atlantic Ocean. The hourly velocity is between six and ten miles, considerably less than that at Cape May. "With the Atlantic on the east and the Gulf of Mexico on the south and west the temperature of Florida, and especially that of the peninsula, is very much ameliorated by the constant sea breezes, and the climate rendered remarkably equable and genial. The regular alternation of land and sea breezes prevents, especially during the hot season, the discomforts and suffering of excessive heat which is usually associated with the wind in the lower latitudes of the North Temperate Zone" (Wall, *loc. cit.*).

The number of clear and fair days is about the same for each of the resorts under consideration, and the yearly average is large, equal to that of San Diego or of Santa Barbara. Three out of four days during the winter months are fair or clear. The average number of rainy days for the year is considerably higher than at Cannes, Nice, or San Remo; but, as before mentioned, the greater part of the rain comes in the summer. It is to be regretted that there are no meteorological data, so far as known to the writer, for points situated upon the elevated ridge in the interior. Such data would probably approximate more nearly to those of Jacksonville and Tampa, which are situated some miles from the coast, and the mean average daily range of these two places, as we have already observed, is considerably greater than is the case with the coast towns.

Of Winter Park, situated 133 miles south of Jacksonville, 40 miles west of the Atlantic Ocean and 80 miles east of the Gulf of Mexico, with an altitude of over one hundred feet, we are told that "the air is fine and dry, the country around being made up of high pine lands, that there are no marshes or stagnant ponds, but instead a chain of beautiful, clear-water lakes. The temperature of the winter days averages from 60° to 65° F. during the twenty-four hours. Occasionally there is a frost, and once in a while freezing temperature occurs at night, but none during the days. It rains very seldom during the winter months, but there are heavy dews night and morning." (Report on Health Resorts, Transactions of the American Climatological Association, 1895.)

The climate of Key West is "essentially tropical, and typically insular." As will be seen in the tables, July shows a much greater amount of precipitation than the winter months, and such is the case with the other summer months; there is practically a dry (winter) and a rainy (summer) season. From this fact, however, it must not be supposed that it rains most of the time in summer, for July, for instance, shows 25.5 clear and fair days, and the other summer months about the same proportion.

It will be also noticed that the temperature is remarkably equable, the mean of the warmest being 91.3°, and of the coldest 66.5° F.; the diurnal range is also very small. The city of Key West, the largest in the State next to Jacksonville (about 25,000 inhabitants), is situated upon a coral island of the same name, seven miles long and from one to two miles broad. There are no springs on the island, and the water supply is derived from rain water or from distillation.

The foliage and fruits are luxuriant and more or less tropical. The streets of the town are broad, the residences are shaded with tropical trees, palms and brilliant flowers grow in profusion, all giving the town a very picturesque appearance.

Key West is not known as a health resort, as are the other well-known resorts in Florida; it is said, however, to be healthy, and it at least possesses an ideal semi-tropical insular climate. Its sanitary condition is unknown to the writer. It is the most southern city of the United States. "The fishing and boating are unsurpassed, and there are a number of charming drives on the island."

The warmth, abundant sunshine, equable temperature, marine atmosphere, and all the varied charms of land and water will always render Florida one of the great winter resorts of the United States. It is easily accessible from the Northern States by rail or by boat, and it possesses an unrivalled system of hotels. As Dr. Wall truly says:

"To the vast majority of the valetudinarian class from other causes than consumption, the winter's sojourn in the mild marine climate of Florida will always be found a powerful adjunct in re-establishing the impaired health."

Finally, to the person who wants a *change* from the exhausting routine of city social or business life and who, from such or other reasons, has become "stale," to speak in athletic parlance, Florida offers a veritable paradise, provided a simple outdoor life is pursued and business and society are abandoned. The writer can speak from personal experience of the keen delight one experiences in the trip up the St. John's or Ocklawaha River; fishing in the Gulf of Mexico or hunting for sea-beans on the shore. With such novel surroundings, mere existence is a pleasure, and the subtile influences of the balmy atmosphere bring renewed health and strength of mind and body.

Edward O. Otis.

FLUKES. See *Trematoda.*

FLUOROFORM WATER (Fluoroformol) is a saturated (2.8 per cent.) aqueous solution of gaseous fluoroform (CHF_3). It is odorless and almost tasteless, but produces a local reaction on the tissues which is evidenced in the mouth by a stinging sensation. Besides its internal use in tuberculosis and acute pneumonia, Stepp of Nuremburg uses it topically as spray or inhalation for respiratory diseases, as local application for lupus, and as injection for tuberculous joints and sinuses. Internally the dose for a one-year child is 4.0 gm. (ʒ i.), and for adult 15.0 gm. (ʒ iv.) several times a day. One hundred grams have been taken in twenty-four hours without inconvenience (Stepp).

W. A. Bastedo.

FŒTUS. See *Embryos.*

FOLLICULITIS DECALVANS.—This disease has been described under many names, such as alopécies cicatricielles innominées (Besnier), folliculite épilante (Quinquaud), acné decalvante (Lailler), ulerythema sycosiforme (Unna), and Brocq would include under it Kaposi's dermatitis papillaris capillitii.

Symptoms.—It may affect the scalp alone, or the bearded portion of the face from which it may extend to the scalp, while the hair of the pubes and axilla do not escape at times. Upon the scalp it takes one of two forms:

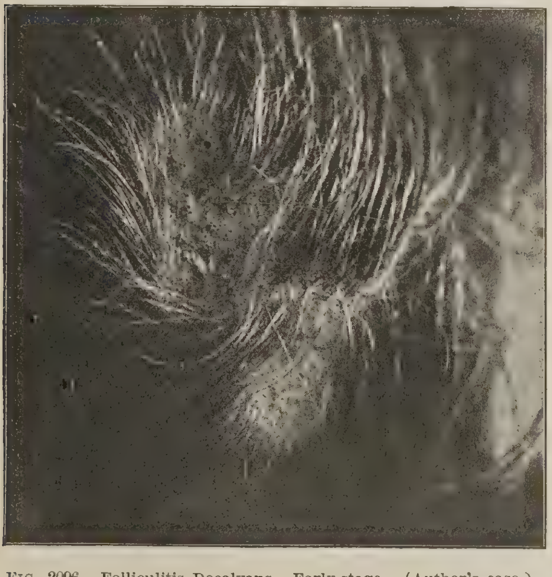

Fig. 2096.—Folliculitis Decalvans. Early stage. (Author's case.)

1. The *alopécie innominée* of Besnier. In this form we find one or more irregular, ill-defined bald patches about which are tufts of hair. Sometimes it will be noted that just beyond the circumscribing tufts of hair are other small bald patches showing the extension of the disease into neighboring parts. The scalp in the patches is cicatricial, thinned, slightly depressed, smooth or stippled over with follicular openings. Signs of active inflammation may be entirely wanting or confined to the mouths of the follicles. At other times there is a slight, diffused redness with furfuraceous desquamation; or there may be some very small and superficial pustules occupying the infundibula of the hair, which in a short time are transformed into depressions out of which the hair falls. As soon as the hair falls all signs of inflammation subside. The hair is permanently destroyed, and the scalp is gradually transformed into a mass of cicatricial tissue. New spots develop here and there in an erratic manner.

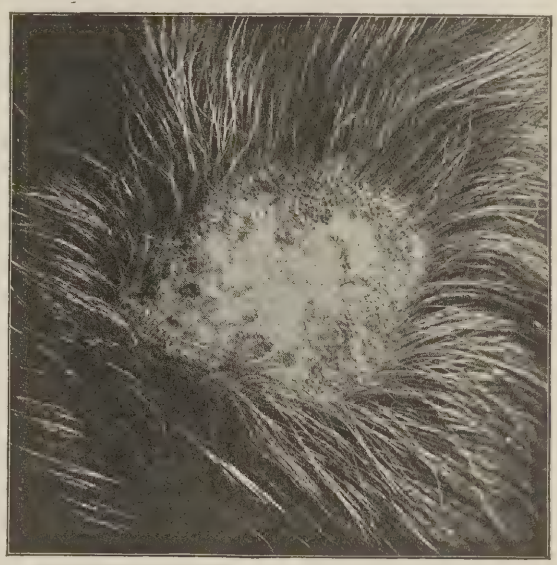

Fig. 2097.—Folliculitis Decalvans. A more advanced stage of the Disease. (Author's case.)

2. This is the *folliculite épilante* of Quinquaud. While the first form is confined to the scalp, the second may also affect the beard, pubes, and axilla. It differs from the first form in being accompanied by more marked inflammation. Like it it produces bald, smooth, irregularly shaped, cicatricial patches. These are scattered through the hair, and are of various sizes up to that of a silver quarter of a dollar. In them are some small red points, while about their edges and in their neighborhood are purulent points, miliary abscesses, and red papules, each with a hair in its centre. The folliculitis causes destruction of the hair which is permanent, giving rise to the cicatricial appearance. If there are a number of patches near each other they will be separated by tufts of sound hair. If the disease occurs on other parts than the scalp it will give rise to similar appearances.

Folliculitis decalvans is a chronic and progressive process, and it is impossible to say how great its ravages will be. It is usually slow in its progress.

Etiology.—Nothing positive is known of the cause of the disease. Some observers have found micro-organisms in relation with it, but we cannot as yet speak positively about these. Inasmuch as some of the cases yield to antisyphilitic treatment, it has been assumed that some of the cases are due to syphilis.

Diagnosis.—Occurring on the scalp it must be diagnosed from alopecia areata and the baldness due to favus. From alopecia areata it is distinguished readily by the fact that it is cicatricial in character, while in alopecia areata the skin is unaltered. Moreover, in the latter disease there are never signs of follicular inflammation. If there are favus crusts or evidences of folliculitis the diagnosis from favus is easy, as in folliculitis decalvans we do not have sulphur-yellow crusts, and in favus we do not have folliculitis. In inactive cases it is impossible to tell which disease we have, as both diseases produce baldness of the same general character. The history of the case will, however, enable us to decide.

TREATMENT.—Thus far, treatment has not been of much avail. Quinquaud recommends washing the patches with soap and water, and painting the scalp in their vicinity with tincture of iodine. Every morning the patches are to be bathed with hydrarg. biniodide, gr. i. (0.065); hydrarg. bichloride, gr. iv. (0.26); alcohol, ℥ ss. (16.); aquæ destillat. ad ℥ iv. (125). Of course the baldness is permanent, the scalp being converted into a cicatrix. *George T. Jackson.*

FOOD AND DRUG INSPECTION.—Modern Legislation Relative to Food and Drug Inspection.—The present article is chiefly devoted to the subject of legislation to provide protection against adulteration and to the amount of work accomplished under such laws.

Popular knowledge upon the subject of food adulteration is undoubtedly derived to a great extent from the occasional publications of the daily press, which are too often of a very sensational character, exaggerating not only the extent of adulteration, but also the comparative ratio of harmful adulteration to that which is merely fraudulent in its character. Fortunately these publications are not so common as they were a few years ago. It is but a few years since a public document, in commenting upon this subject, stated that "fraudulent adulteration is but little more common than injurious adulteration." An examination of the food supply of almost any community at the present day would undoubtedly show the incorrectness of this statement.

ENGLAND.—The history of food adulteration in England dates from a very early period. In the reign of King John, the price and size of the loaf of bread were regulated by law, and this law was afterward amended so as to provide penalties for adulteration, these consisting of fine, capital punishment, and the pillory. During the reign of Edward the Confessor punishment for brewing bad beer was publicly enforced, and in 1589 "this beverage could not be sold without the approval of official 'ale-tasters.'"

Addison says in the *Tatler* (1710): "These subtle philosophers are daily employed in the transmutation of liquors, and, by the power of magical drugs and incantations, raise under the streets of London the choicest products of the hills and valleys of France; they squeeze Bordeaux out of the sloe and draw champagne from an apple."

Modern agitation in England upon the subject of restricting food adulteration may be said to date from about the middle of the last century. From 1851 to 1854 the subject was often discussed in the columns of the *Lancet*, and a Parliamentary inquiry was finally ordered. After the report of the Committee of Investigation the first general English law was enacted, and was known as the Adulteration of Food Act of 1860. This act authorized the appointment of analysts by local boards, and made £5 the penalty for selling an adulterated article, the vendor knowing it to be such. For a second offence the offender's name and place of business could be published in addition to the fine. The Act was permissive as to the appointment of analysts, and was never satisfactorily enforced. In 1869, and again in 1871, bills were introduced in Parliament to improve the law, but failed to pass. In 1872, however, an act was passed which obliged the local boards to appoint analysts and provide for inspectors. The penalty for adulterating articles of food was fixed at £20 for a first offence, and for a second the name and residence of the delinquent could be published in a newspaper. The punishment for adulterating drugs was made £50 for a first offence, and for a second imprisonment not exceeding six months. Previous to 1874 there were various attempts to enforce this law, but without noticeable success, owing to the lack of recognized standards of purity, the disagreement of analysts, and the varying decisions of magistrates in regard to the meaning of the term adulteration. In 1874 a new Parliamentary investigation was ordered and more scientific examination made of the whole subject of adulteration than had been secured before. The report of the committee was reassuring, and was to the general effect that the public was more cheated than poisoned by the adulterations generally practised. In 1875 a carefully digested measure was passed by Parliament (38 and 39 Vic., c. 63), and this, with the amendments of 1878, 1879, and 1899, is now the law for Great Britain.

The principal provisions of the law are as follows:

First. No person shall mix, color, stain, or powder any article of food with any ingredient or material injurious to health, with intent that the same shall be sold in that state, and no person shall sell any such article under a penalty not to exceed £50 for the first offence, and every offence after a conviction shall be a misdemeanor, to be punished by imprisonment not to exceed six months.

Second. No person shall mix, color, stain, or powder any drug so as to affect injuriously the quality or potency of such drug, with the same penalties as provided in the case of food. Proprietary medicines and patented articles are excepted, as are also substances which are added merely to make the compound fit for carriage or consumption, and are not injurious to health.

Third. A person is not guilty, under the act, who proves that he did not know of the adulteration, and could not have obtained such knowledge with reasonable diligence.

Fourth. Mixtures containing articles not injurious to health, and not intended fraudulently to increase the bulk or weight, can be sold, if labels are affixed plainly stating that the substance is a mixture.

Fifth. Analysts are to be appointed, and any medical officer or private person can bring articles to be analyzed. The seller is to be informed that the article is purchased for analysis, and it is to be divided into three parts, one of which is to be kept by the seller if he desires, one given to the analyst, and one kept by the purchaser. A penalty of £10 is imposed for a refusal to sell.

Sixth. The seller cannot be convicted if the article sold is in the same state as when purchased by him, and he has a warranty from the manufacturer.

Seventh. A person forging a warranty is liable to two years' imprisonment. A false warranty makes the giver liable to a penalty of £20, and the same penalty is imposed for applying a warranty to a wrong article.

Eighth. A person upon whom a fine is imposed can recover the amount with costs from the person from whom he bought the adulterated article, if it was sold to him as of the quality for which he sold it to the last purchaser, and that he did not know it to be otherwise.

In addition to the general acts referred to, frequent statutes have been passed in regard to sophistications of special articles.

Adulterations of coffee were prohibited by acts passed in 1725, 1803, and 1822. Since the latter date there have been various Treasury regulations, the result of which was largely to permit the mixture of chicory and other ingredients with pure coffee, and in some cases an entire substitution of the imitations. Adulterations of tea were prohibited by an act passed in 1725, and other acts were passed in 1731, 1773, and 1824. Wines, liquors, ale, and beer have been the subject of frequent statutes from the earliest times. In the reign of Edward III., the Vintners Company was incorporated under the title of the "Wine Tonners," and power was given to examine wines and liquor offered for sale, and to confiscate any adulterated samples. They could also place the sellers in the pillory.

In the time of Queen Anne, the use of cocculus indicus was forbidden in brewing beer, and further legislation was passed in 1816, 1830, and 1863. The Licensing Act of 1872 is the present law on the subject, and the penalties imposed are £20 for the first offence, and £100 for the second. Tobacco and snuff adulterations are mentioned only in the more recent Parliamentary acts. The laws on the subject were passed in 1843, 1862, and 1868.

The adulteration of seeds used in agriculture has been found to be a serious injury to the farmers of Great Britain, and by the act of 1869, the killing * or dyeing of seeds is punished by a fine of £5 for the first offence, and £50 for the second, together with the publication of the offender's name at the discretion of the justice. The adulteration of drugs is prohibited and punished by the general acts of 1860, 1872, and 1875, but there have been a number of special acts relating to the subject. In the city of London, by laws passed in the reigns of Henry VIII. and Queen Mary, power was given to the College of Physicians to search for defective or corrupted drugs and medicines, and to punish the offenders by imprisonment and fines not to exceed £20. This power still belongs to the College of Physicians, but has not been recently exercised. The Pharmaceutical Society of Great Britain, founded in 1841, has been very active and influential in securing the passage of the recent laws relating to drugs and their enforcement.

The organization of the British Society of Public Analysts has proved to be a decided stimulus to the work of food inspection. This society was established in 1874 and its work as a society, together with its publications, has aided very greatly in carrying out the provisions of the Food Acts in establishing standards of purity and in formulating definitions of adulteration.

In 1896, after several years' experience under the Food and Drug Acts of 1875 and later years, it was deemed necessary to make certain changes in the statutes, and a new Parliamentary inquiry was ordered. The committee having charge of the inquiry reported certain recommendations to the Parliament, and after discussion an amended act was passed (62 and 63 Victoria, chap. 51). One of the chief objects of this act was to secure the agricultural interests of the country against the fraudulent sale of oleomargarine.

Section 1 of this act provides penalties of £20 to £100 if, (*a*) margarine or margarine cheese are imported into the United Kingdom, except in packages conspicuously marked as "margarine" or "margarine cheese" as the case may require.

(*b*) If adulterated or impoverished butter, or adulterated or impoverished milk or cream, is so imported, except in packages or cans conspicuously marked with a name or description indicating that the butter or milk or cream has been so treated.

(*c*) If condensed, separated, or skimmed milk, except in tins or other receptacles bearing the labels, "Machine skimmed milk" or "skimmed milk" as the case may require, in large and legible type, or

(*d*) Any adulterated or impoverished article of food to which the law may be applied, unless the same is imported in packages or receptacles conspicuously marked with a name, or description indicating that the article has been so treated.

Under this act an article is deemed to be adulterated or impoverished if any part of it has been abstracted, so as to affect injuriously its quality, substance, or nature. It is not to be deemed adulterated, by the addition of preservatives or coloring matter if these do not render it injurious to health. Prosecutions are to be undertaken by the Commissioners of Customs.

By Section 2, the officers of the Local Government Board and of the Board of Agriculture are empowered to procure samples for analysis. Section 3 makes it the duty of local authorities to appoint public analysts. If the local authorities neglect their duties in relation to the food acts, the Local Government Board is authorized to enforce the law and to charge the expenses to the defaulting local authorities.

Public analysts must satisfy the board of their competency.

By section 4, the Board of Agriculture can make regulations concerning the standard quality of milk products.

Sections 5–8 relate to the sale of margarine and imitation cheese.

Section 9. Name and address of vendor to be inscribed on his vehicle.

Section 10. Division of samples taken for analysis.

Section 11. Receptacles to be properly labelled.

Section 12. Labels to be legibly printed.

Section 16. Provides penalties for obstruction and bribery.

Section 19. Proceedings to be instituted within twenty-eight days after sale.

Section 23 and 24 apply the act to Scotland and Ireland. This act became effective January 1st, 1900.

The following statement from the Twenty-eighth Annual Report of the Local Government Board of England for 1898–99, shows the advantages of food and drug inspection in England and Wales since the beginning of Operations under the Food and Drug Acts in 1876.

The total number of analyses of food and drug samples made in 1898 was 49,555 * or about 1,600 more than those of the previous year. The increase in the annual amount of work performed has been quite constant for the past twenty-two years. In the five years 1877–81 the average number of samples examined per year was 16,688 or one to every 1,520 of the population; in 1882–86 it rose to 21,772, or one in 1,237; in 1887–91, it was 26,846, or one in 1,060, and in 1898 it was 49,555, or one in 585. In London one sample was examined for every 353 persons, and in the provinces one for every 659. But in some quite populous districts, the provisions of the acts were imperfectly carried out, and in commenting upon the neglect of the authorities in these districts the Board says: "The degree, however, in which the acts were utilized was by no means uniform in different districts. Within the jurisdiction of ten County Councils, extending over an aggregate population of 910,032, only 180 samples were analyzed, or one sample a year for every 5,056 persons; and in sixteen boroughs, with an aggregate population of 405,239, only 68 samples were analyzed, or one for every 5,959 persons." †

RESULTS OF EXAMINATIONS MADE IN ENGLAND AND WALES BY THE PUBLIC ANALYSTS, UNDER THE FOOD AND DRUG ACTS, 1877–1898.

Character of samples.	Number of samples examined in 1898.	Adulterated.	PERCENTAGE OF ADULTERATION.					
			1898.	1897.	Five-year Periods.			
					1892–1896.	1887–1891.	1882–1886.	1877–1881.
Milk	20,315	2,011	9.9	10.4	12.3	13.2	16.7	21.1
Bread	717	6	.8	1.4	.7	1.4	3.4	6.6
Flour	1,013	20	2.0	.0	.2	3.0	.5	2.5
Butter	9,375	998	10.6	10.3	10.8	13.4	17.9	13.9
Coffee	1,879	187	10.0	9.6	11.1	14.8	17.8	18.6
Sugar	584	17	2.9	7.5	3.9	4.6	....	1.2
Mustard	775	30	3.9	5.5	6.6	9.2	14.5	17.4
Confectionery, etc	488	14	2.9	5.3	3.2	3.2	2.7	2.8
Pepper	1,566	13	.8	.1	1.0	7.5	....	....
Tea	486	15	3.1	.2	.05	.1	....	....
Lard	1,421	2	.1	.7	3.6	7.9	...	....
Wine	84	2	2.4	2.4	4.7	4.7	4.4	14.2
Beer	256	1	.4	2.8	6.9	2.6	3.0	5.4
Spirits	4,872	603	12.4	15.1	17.6	18.5	22.3	34.9
Drugs	1,641	196	11.9	10.5	12.3	13.1	13.6	22.0
Other articles	4,083	204	5.0	7.1	8.3	7.5	....	....
Total	49,555	4,319	8.7	9.4	10.6	11.7	13.9	16.2

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* This term "killing of seeds" is interpreted in the British Statutes (Chap. 112, 32 and 33 Victoria) as meaning "to destroy by artificial means the vitality or germinating power of such seeds."

* The Report of 1899-1900 (p. cxlv.) shows that 53,056 samples were examined in 1899, of which 9.4 per cent. were adulterated, and in 1900 62,858 samples were examined, of which 8.8 per cent. were adulterated.

† Report of Local Government Board, England, 1898–99.

In the foregoing table the five-year periods show a marked improvement if we compare the earlier with the later.

The comments of the Local Government Board show that the practice of milk adulteration in the cities of England differs but little from that which prevails in the large cities of the United States. The accounts of prosecutions which fill the pages of the *British Food Journal* confirm the same statement.

The whole number of samples of milk examined in England in 1898 was 20,315, or about two-fifths of all samples of food examined. Of these 2,011, or 9.9 per cent., proved to be adulterated. As might be expected, the samples obtained in cities were much more adulterated than those procured in the country districts.

In London the percentage of adulterated samples was 12.9. In Oldham, Huddersfield, Bradford, Cardiff, Salford, and Manchester, the rate of milk adulteration was only 2.1 per cent., while in six other cities, Liverpool, Birmingham, West Ham, Sunderland, Portsmouth, and Nottingham, it was as high as 20.3 per cent.

The Board says in regard to milk: "It is difficult to account for the great disparity between the rates of milk adulteration in these groups of towns, but part of it is probably due to differences in the methods of procedure adopted by the analysts. In certain towns every sample of milk submitted to the analyst is examined for the presence of boric acid, formalin, or other preservative, and the sample is condemned if only a small percentage of the preservative is discovered. In such cases the rate of milk adulteration appears to be relatively high, when compared with that of other districts in which the presence of preservatives is not regarded as of itself rendering the sample of milk liable to condemnation. Some analysts pass as genuine all samples, equal in quality to the poorest milk yielded by an individual cow, and some condemn only those respecting which there is a reasonable probability that legal proceedings, if instituted, will be successful. Others, again, hold it to be their duty to report unfavorably on every sample which fails to reach a somewhat high standard. We understand, also, that in certain districts it is the practice to test samples of milk with a lactometer or other similar instrument, and that only those that are suspected of adulteration are transmitted to the analyst for chemical analysis."

"Occasionally some instances of gross adulteration of milk are brought to light. One sample taken in Sheffield was reported by the analyst to contain as much as 85 per cent. of added water. In another case a man trading in several towns in the south of England under the name of the 'Farmers' Direct Milk Supply Company' admitted at his trial at Southampton, that for many months he had daily and systematically adulterated, by the addition of one-fifth of separated milk, the whole of the milk sent by him for retail sale to Southampton and Bournemouth."

"We have received a large number of representations as to the injurious effects upon infants likely to follow upon the consumption of condensed separated milk, which is almost entirely devoid of fat, and therefore contains but little (if any) nutriment.* It is stated that it is necessary to consume the contents of at least ten half-pound tins of condensed separated milk in order to obtain the nutriment yielded by a pint of good new milk. It is satisfactory to note that some local authorities have taken steps to make known throughout their districts that it is dangerous to use condensed separated milk for the feeding of infants."

Two-thirds of the samples of butter submitted by private purchasers and 55 per cent. of those submitted by agricultural societies were condemned. If we exclude the samples taken on behalf of these associations and by private purchasers, the rate of butter adulteration in London is found to be 14.2 per cent.; in the 32 great towns 12.9, and in the remainder of the country only 4.4 per cent.

Of the 1,879 samples of coffee examined 10 per cent. were condemned. As usual, many samples were reported to contain large quantities of chicory. In one case in Cheshire a sample was found to contain sugar. The analyst states that "this was probably due to the practice of roasting coffee with a certain proportion of sugar, which will increase the weight of the coffee from 5 to 10 per cent. This admixture is so skilfully done that each berry is coated with sugar, and any one buying his coffee in the berry would think he was obtaining it pure. Some may say this is an innocent adulteration, but it is at the same time a most profitable one, for the sugar, which is not much more than one penny a pound, is sold at the rate of a shilling or more."

Seventeen of the 584 samples of sugar were reported against, and 12 fines, amounting to £11 15s., were imposed.

Of 575 samples of mustard examined, 30 were condemned, and six small fines were inflicted.

Four hundred and eighty-eight samples of confectionery and jam were analyzed, and 14 were found to be adulterated, there being one conviction.

Thirteen samples of pepper out of 1,566 taken were reported against, and the vendors of three of them were fined.

Of the 1,421 samples of lard analyzed, all but 2 were found to be genuine. This is in striking contrast to the figures of 1888, when cotton-seed oil was extensively used to adulterate lard, and 299 samples out of 1,782 were condemned.

Eighty-four samples of wine were examined, and 2 were found to be adulterated.

Of 256 samples of beer, 1 was reported against on account of the presence of over 100 grains of salt per gallon. Apart from the presence in beer of salt in excess, it is difficult for analysts to pronounce beer to be adulterated, as under the present law beer may be manufactured by brewing any substitute for malt with any substitute for hops.

The percentage of adulteration of spirits is again higher than that of any other article specifically mentioned in the table.

There were 1,641 samples of drugs examined, of which 196, or nearly 12 per cent., were found to be adulterated. In only 93 of these cases were legal proceedings taken. There were 79 penalties, amounting in all to £53 0s. 6d. There were 39 samples of sweet spirits of nitre adulterated, out of 173 examined; of Gregory's powders 25 out of 75; of sulphur 15 out of 82; of rhubarb 15 out of 186; of lime water 13 out of 40; of magnesia 11 out of 44; and 8 out of 25 prescriptions were improperly or carelessly compounded. There were also 8 samples of wax condemned out of 30 analyzed; 9 out of 84 of cream of tartar; and 9 out of 43 samples of seidlitz powders.

Out of the 2,011 samples of milk reported as adulterated in 1898, 1,205 were the subjects of legal proceedings. In 986, fines were imposed amounting to £1,652 (about $8,250).

The use of poisonous pigments in England, as elsewhere, appears to have nearly or quite disappeared under the protection of the Food and Drug laws.

France.—In France, as early as the year 1396, there was an ordinance of the city of Paris forbidding the coloring of butter with herbs, flowers, or drugs, and there were laws, dating from about the same time, regulating the purity of bread, wine, and other food products. In 1802 the Conseil de Salubrité was established at Paris and this was followed by the organization of various health boards to whom the French are now mainly indebted for their present immunity from food adulteration.

In France, at the present time, there is a law establishing laboratories in the principal cities for the analysis of articles bought by private persons, or secured by duly appointed inspectors, who have power to punish offenders. The officials provided for the laboratory work and the inspection of the markets and stores are a director, inspectors, and chemists. In connection with the laboratories there are elaborate photographic apparatus provided, so that juries can judge by ocular demonstration of many forms of adulteration.

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*The insertion of these words ("if any") is a manifest error. Skimmed milk has a decided food value, but not so great as that of whole milk. [Ed.]

Paris.—The work of examining the food supply of Paris has been conducted at the Municipal Laboratory, on the north bank of the Seine, during the past twenty years. Prof. C. Girard is the chief chemist in charge. Two printed reports of this laboratory have been published, dated 1882 and 1885. A monthly bulletin is also published detailing the work of the laboratory during each month.

By decision of the Municipal Council gratuitous qualitative analyses are made at this laboratory of such articles of food and drink as are deposited at the laboratory for this purpose. The greater part of the articles examined is collected by inspectors authorized to visit shops and markets where food is sold, for the purpose of making collection of such samples. These inspectors also have authority to destroy unsound food. Their collections are generally made from such kinds of food preparations as are suspected of adulteration or are especially liable to this species of fraud. Hence the monthly bulletins issued from the laboratory do not represent the actual condition of the markets, since many articles of food are not liable to adulteration. The number of articles examined in each year amounts at present to more than 25,000 annually. The scope of the analyses embraces several articles in common use besides food, such as children's toys, wall-paper, cooking utensils, preparations used in embalming, coloring matter, cosmetics, and illuminating oils.

The following condensed statement, compiled from the monthly bulletins for the year ending March 31st, 1900, will give a fair illustration of the work accomplished in Paris during that period: Number of visits made to markets and shops, 53,437.

Under the present classification articles are divided into three groups, good, passable, and bad.

The total number of articles collected for examination by the inspectors or collectors of samples was 26,583; of this number 48.2 per cent. were classed as good, 25.8 per cent. as passable, and 26 per cent. as bad.

There were also 969 samples for which a fee was paid for analysis, and 244 samples were deposited at the laboratory by citizens for gratuitous examination.

Classification of Work of Municipal Laboratory of Paris for the Year Ending March 31st, 1900.

Articles examined.	Good.	Passable.	Bad.
Wines	1,408	3,428	2,520
Vinegar	62	66	45
Beer	464	198	137
Cider	43	43	156
Spirits	402	970	249
Syrups	339	8	218
Water and ice	749	250	319
Milk	1,360	1,388	1,698
Butter and cheese	2,036	246	231
Lard	113	25	50
Oils used as food	107	12	75
Bread and cake	591	58	158
Flour	918	68	96
Sugar and confectionery	731	88	273
Preserves and honey	78	7	171
Chocolate and cocoa	240	33	133
Coffee and tea	972	60	29
Meat	715	37	237
Pepper and spices	873	4	96
Tinware and crockery	186	10	118
Toys and colors	68	3	21
Petroleum	301	10	20
Fireworks	....	....	37
Drugs	47	....	14
Embalming material	7	5	....
Miscellaneous	400	115	109

The principal adulterations found in the articles named in this list were the following:

Wines were either watered, fortified, sugared, plastered, or treated with salicylic and boric acids as preservatives. Beer was watered, or treated with glucose, sugar, and other materials. Cider was colored and treated with sugar or tartaric acid. Spirits were either watered or fortified by the addition of alcohol. Syrups contained glucose and artificial coloring matter. Water contained an excess of mineral and organic matter and in one sample lead was found. Milk was watered, skimmed, colored, or treated with preservatives, including formalin. Butter contained margarine, boric acid, and an excess of water. Lard was adulterated with cheaper fats and cotton-seed oil. Olive oil was adulterated with cheaper oils. Bread and flour were found to contain cheaper flour or meal than was called for. Sugar and confectionery contained glucose. Honey and preserves were adulterated with glucose and coloring matter. Meat was treated with salicylic and boric acids. Tin and earthenware contained lead. Pepper and spices contained starch, ground olive stones, nutshells and other foreign matter. Toys were colored with forbidden colors. Illuminating oil ignited at a lower temperature than 35° C. (95° F.). Drugs were found to be below the required standard.

In the recent years of work, bacteriological examinations were made in addition to chemical analysis of certain articles as follows. In the past year: Of wine, 380 samples, of milk 44 samples, of water and ice 1,849 samples, and of cider 8 samples. Of the water 828 samples were pronounced good, 651 passable, and 320 contained pathogenic germs and were condemned.

Germany.—In Germany there were enacted at a very early date laws inflicting severe penalties for selling adulterated bread, drugs, or wine. "In the fifteenth century, at Bieberich on the Rhine, a wine adulterator was forced to drink six quarts of his own stock and it is recorded with due gravity that the test resulted fatally" (Battershall, "Food Adulteration," p. 3). The statutes now in force were passed quite recently—one in 1872, regulating the sale of drugs, and another in 1879, relating to food. By the law of 1872, the German Pharmacopœia was made the standard of purity. In 1878, 231,478 samples of food, drink, drugs, etc., were examined, and there were 3,352 convictions for violations of the law. The penalties are fines or imprisonment, and it is not necessary to prove that the seller was aware of the adulteration. The following general laws relating to food inspection are in force.

By a law enacted in 1879 police officers are authorized to enter shops where food is offered for sale and to take samples.

Imitation or adulteration of food and stimulants with a view to deception, the sale of putrid, falsified, or adulterated food and stimulants, and offering them for sale under a description calculated to deceive the purchaser, are forbidden. The manufacture, sale, or traffic in food stimulants and other necessaries, whose consumption or use is injurious or may destroy health, is forbidden by heavy penalties (in some cases by imprisonment).

The application of these general principles is further facilitated by the following special enactments with reference to particular necessaries of life.

1. Petroleum, which parts with inflammable vapor at a lower temperature than 60° F. must be kept in vessels bearing the inscription "inflammable" in large indelible letters in a prominent position.

2. Eating, drinking, and cooking utensils must not be made of lead, or of any alloy containing more than ten per cent. of lead, they must not be coated internally with any metallic alloy containing more than one per cent. of lead. The latter regulation applies to all objects which come in direct contact with the mouth, or are used for preserving meat, fruit, spirits, etc. These precautions are for the prevention of lead poisoning.

3. No coloring agents can be used in the manufacture of food or stimulants, which contain any of the following substances: arsenic, antimony, barium, lead, cadmium, chromium, copper, mercury, uranium, zinc, tin, gamboge, coralline, or picric acid. Such colors cannot be used in the wrappings of provisions, in making soap, or other preparations for the skin or hair, in manufacturing toys, etc. In particular, the use of arsenical coloring is strictly forbidden in the manufacture of carpets, curtains,

wall-papers, paints, furniture, artificial flowers, clothes, type, etc., etc.

4. The sale of imitations of butter is forbidden, unless they are distinctly labelled and sold as margarine, etc.

5. By a law of February 1st, 1891, the use of machines for the manufacture of artificial coffee berries is forbidden.

6. By a law of April 29th, 1892, the addition of a number of specified harmful substances to wine is forbidden. Definite limits are also laid down relative to the use of other adulterations of wine.

Hamburg.—Drs. Dunbar and Farnsteiner report upon the inspection of food and drinks in Hamburg (*Rev. des Falsifications*, vol. xii., p. 111). Of medicinal wines, 22 out of 102 samples were condemned either for the addition of sugar, or salicylic acid, or other impurities; 11 out of 81 sweet wines were condemned for similar causes. Also 27 out of 212 German wines, 12 of which contained too little extractive matter, 3 out of 23 samples of beer were condemned; 2 out of 20 samples of vinegar; 21 out of 56 specimens of sausage and hashed meat were condemned on account of artificial color and excess of sulphurous acid.

Dresden.—Dr. Heinze, of Dresden, reports upon the examination of 1,781 samples of food made during 1898 (*Revue Internationale des Falsifications*, vol. xiii., April, 1900, p. 37). Of this number 590, or 33 per cent., were condemned. Of 170 specimens of butter, sold as such, only 4 proved to be margarine. Out of 69 samples of vinegar, 35 were of inferior strength. One hundred samples of sausage were examined and 58 were artificially colored. Three contained boric acid in small quantity. Of 269 samples of spices, 27 were condemned.

Three hundred and forty-one samples of milk were examined, and 267, or 77.7 per cent., were condemned as adulterated.

The high percentage of adulteration in some of the foregoing articles is accounted for by the fact that the police authorities charged with their collection were also instructed in the methods of making rough tests of purity, so that they were enabled to select for final examination an unusually large number of adulterated articles.

The chemist also reports upon 72 samples of children's toys, whistles, musical instruments, tin preserving cans, covers of beer mugs, etc., which were examined for lead, and of this number 49 were condemned.

Altona.—Dr. Reinsch, director of the Municipal Laboratory of Altona, reports upon the work of the year ended March 31st, 1899 (*Revue Internationale des Falsifications*, vol. xii., December, 1899, p. 179); 2,612 specimens were examined, of which 950 where articles of food and cooking utensils, 360 were samples of the public water supply, 965 were of the city gas supply.

One hundred and forty-three of the food samples, or 15 per cent., were condemned as adulterated or injurious to health.

Twenty-four out of 187 specimens of butter, or 12.8 per cent., contained more than 16 per cent. of water. Fines were imposed from 20 to 150 marks.

Of 348 samples of milk, 77 were adulterated either by skimming or watering.

Breslau.—The report of the official chemist of Breslau for 1898–99 embraced a wide field of objects. The principal articles examined were: butter, 326 samples, 28 adulterated; milk 341 samples, 12 adulterated; sausage, 93 samples, 2 adulterated. The general ratio of adulteration reported was very small.

One hundred samples of vinegar were examined, and the acetic acid varied from 1.4 to 5.8 per cent.

The samples of milk varied in their fat contents from a minimum of 2.40 to a maximum of 11.2 per cent. Thirteen samples contained over 6 per cent. of fat in each. The total solids in the lowest sample were 6.58 per cent., indicating an addition of 45 per cent. of water.

Three hundred examinations of illuminating gas were made on as many working days during the year.

Other examinations were also made of beer measures containing lead, lamp-shades containing arsenic, children's toys, etc.

HOLLAND.—Dr. Lam, commercial chemist at Rotterdam, reports upon the work of inspection for the year 1898 (*Revue des Falsifications*, vol. xii., p. 128).

The whole number of examinations was 5,438, of which 548, or 10.1 per cent., were condemned, the principal adulterations being as follows: Milk, 3,942 samples, 169 adulterated. Spices, 147 samples, 54 adulterated. Coffee and tea, 51 samples, all genuine. Cocoa, 43 samples, 32 adulterated. Vinegar, 500 samples, 143 adulterated.

AUSTRIA-HUNGARY.—Dr. M. Mansfeld, director of the Laboratory at Vienna, reports upon the food preparations collected during the year ending August 31st, 1899.

The whole number of samples examined was 1,028, of which 349, or 34 per cent., were condemned as adulterated, or injurious to health. Of 8 samples of beer, 2 were adulterated; of 42 samples of strong spirits, 13 were adulterated. Of butter, 23 out of 76 specimens were adulterated. Of cocoa, 15 out of 50 specimens were adulterated.

Several substances sold as preservatives were examined and found to contain salicylic and boric acids and formalin. An American sausage was found to contain boric acid; one specimen was colored with carmine. Of 39 samples of spices 21 were falsified. Pepper contained starch, ground olive stones, sago, and nutshells. Two samples of honey were adulterated with glue. Several coffee substitutes were examined and found to contain starch, chicory, barley, turnip, and figs. Five samples of lard out of 18 contained other fats and cotton-seed oil. Of wine, 62 specimens out of 175 were adulterated with glycerin, alcohol, sugar, plaster, and artificial coloring matter.[*]

SWITZERLAND.—In Switzerland the work of examining articles of food and drink is well organized by the appointment of a competent chemist in each canton, whose duties embrace the analysis of all articles in domestic use, where a chemical analysis may be required.

St. Gall.—Dr. Ambühl, canton chemist of St. Gall, reports upon 3,954 samples of food examined in 1898, of which 754 or 19.1 per cent. were condemned (*Revue Internationale des Falsifications*, vol. xii., 1899, p. 152).

Of 1,940 specimens of milk, 93 were condemned. Of 124 samples of butter, 40 were condemned. The addition of flour to sausages has nearly ceased. Out of 27 samples of American dried fruits, 15 contained zinc. Out of 775 samples of wine 254 were condemned, being either diluted, fraudulently marked, or otherwise adulterated. The use of lead in the manufacture of cooking utensils was prohibited in this canton as early as 1808.

Basel.—The chemist of canton Basel reported as follows for the year 1899[†]:

Whole number of examinations made, 5,469. Number adulterated, or of bad quality, 411. The list is as follows:

Articles examined.	Total.	Adulterated.
Beer	19	2
Bread	5	1
Butter	388	45
Cocoa and chocolate	13	6
Chemicals	350	....
Preservatives	1	....
Cosmetics	4	4
Vinegar	255	63
Colors	4	1
Meat and sausages	64	5
Fruits	3	3
Fodder for animals	4	1
Spices	162	4
Honey	62	7
Coffee	20	4
Meal	41	....
Milk	2,712	95
Petroleum	3	....
Lard and other fats	204	11
Soap	9	....
Oils	75	7

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[*] "Falsifications observées en Autriche-Hongrie." Extrait du Rapport, par M. le Dr. M. Mansfeld, Directeur de la Laboratoire à Vienne. Revue Internationale des Falsifications, February, 1900, p. 3.

[†] "Verwaltungsbericht des Sanitäts-Departments über das Jahr 1899," Baselstadt, 1900.

Articles examined.	Total.	Adulterated.
Toys	1	....
Spirits	15	2
Water	285	....
Wine	493	111
Sugar	59	20
Examinations for poisons	28	....

Fines were imposed in 143 instances, chiefly for adulteration of milk, wine, sausages, vinegar, and butter.

Berne.—Dr. Schaffer, canton chemist of Berne, Switzerland, reported upon the following articles in 1900, from which it appears that the scope of the canton chemist's authority extends to other articles in domestic use as well as to food and drugs.

	1900.	
	Number examined.	Number found adulterated.
Beer	8	1
Brandy and spirits	128	45
Bread and cake	9	3
Butter	21	5
Vinegar	4	0
Meats	9	4
Cereals	15	4
Honey	3	1
Coffee and tea	19	10
Cocoa and chocolate	21	2
Cheese	4	1
Milk	204	79
Pepper	3	0
Saffron	3	0
Cloves	3	2
Water	520	68
Fats and oils	31	8
Wine	407	145
Preserved fruits	2	2
Sugar	6	1
Miscellaneous	27	6
Proprietary medicines	14	5
Examinations for poisons	27	12
Syrups	12	3
Articles of household use	160	36

In addition to the foregoing the chemist reports upon several proprietary articles, paints, metals, chemicals, clothing, wall-paper, coal and coal-oil soap, and washing-powders, compressed yeast, insect-powders, fire-extinguishers, ice machines, etc.*

UNITED STATES.

In this country most of the States have laws prohibiting adulteration in general, or special forms of it, and many of the larger cities have, in addition, municipal regulations to prevent the sale of harmful products. In the summary of food acts presented in the third volume of the REFERENCE HANDBOOK by Mr. Riley, in 1886, it was stated that there were four States in which no legislation had been enacted in regard to food. In a later summary presented by Dr. C. V. Chapin, in his work on "Municipal Hygiene" (1901), it appears that every State has enacted legislation upon the subject, although in several instances this legislation had reference to special articles of food and in some cases to such as were of comparatively little importance. In some of the States, public sentiment has not been aroused so as to secure a thorough enforcement of the laws, or else adequate appropriations have not been made for the proper performance of the preliminary work of analysis. As a result, the effects accomplished by legal methods have not been so satisfactory as could be desired. The condition of affairs is, however, steadily improving, the people are coming to see the great need for rigorous enforcement of the laws, and experience has shown in what directions the legislation already had, has proved defective.

Congress has passed no general law concerning adulteration of food and drugs, and such would not be greatly needed, except as regards the importation of adulterated articles, if all the separate States had adequate laws on the subject. A bill prepared under the auspices of the National Board of Trade was presented to Congress in 1880, but failed to be enacted. As early as 1848 Congress passed an act to prevent the importation of adulterated and inferior drugs and chemicals, and examiners were appointed. This law seems to have been much needed, for at New York alone, in nine years from 1848 to 1857, over 900,000 pounds of adulterated drugs were seized. For some time past the law does not seem to have been enforced, and the examiners have not made reports to the Treasury Department. No rules have been adopted to secure the systematic prosecution of the work.

Soon after the passage of the English Adulteration Act of 1875, a general interest in the subject was awakened in the United States, and legislation soon resulted. The way for this had largely been paved by the previous examination of adulterations of food by the State boards of health of some of the States, such as Massachusetts and Michigan. The lead in this agitation was taken by the *Sanitary Engineer*, a paper published in New York City, and through its efforts three prizes were offered for the best essays on the general subject of adulteration of food, accompanied by drafts of a law. This competition was established in 1879, and in October, 1880, a report was made by a committee consisting of Dr. John S. Billings, U. S. A.; ex-chancellor Williamson, of New Jersey; Prof. Charles F. Chandler, of New York, and A. H. Hardy, Esq., of Boston, awarding the first prize to George W. Wigner, of London, one of the English public analysts. The law framed by the committee was submitted to the legislatures in several of the States, and in its material parts became a law in New York and New Jersey in 1881, in Massachusetts in 1882, and still later in Ohio, Connecticut, California, District of Columbia, Illinois, Indiana, Kansas, Kentucky, Michigan, Mississippi, North Carolina, Oregon, Pennsylvania, Tennessee, and Wisconsin.

The committee, in making their report, stated that the investigation showed that the adulterations practised were not so injurious to health as had been claimed, and that legislation was needed more for commercial than sanitary reasons. At nearly every session since the 50th Congress, a bill for the prevention of food and drug adulteration has been favorably considered, but has not yet reached the stage of enactment. In 1892 Senator A. S. Paddock, of Nebraska, introduced a bill intended to prevent adulteration of food, but the bill was defeated, as would appear from the published debate upon it, by the vigorous efforts of certain Senators, who represented States in which the production of cotton-seed oil was largely conducted. A more recent bill known as the Brosius bill appears to have a fair prospect of becoming a law (June, 1900). This bill (H. R. 9677, 56th Congress, 1st session) provides:

Section 1. That the Secretary of Agriculture shall organize the Chemical Division of such Department into a bureau of chemistry, which is charged with the inspection of food and drug products and the analysis thereof. He is to publish the results of examinations and analyses. This Department is fully equipped, both in experienced men and in laboratory arrangements to carry out the work designed in this bill, more economically and thoroughly than any other branch of the Government.

Section 2. By this section adulteration or false handling of food and drugs is prohibited, and penalties are provided for violation of the law.

Section 3 provides for the examination of samples of food and drugs offered for sale in original packages in the District of Columbia, or in the Territories, or in any State other than that in which the same shall have been manufactured or produced.

Section 4 defines the duty of the district attorney.

Sections 5 and 6 contain the definitions which are practically the same as those which have existed for several years in New York, Massachusetts, New Jersey, and other States.

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* "Bericht über die Thätigkeit des kantonalen chemischen Laboratoriums in Bern im Jahr 1900," Bern, 1901.

Section 7 provides for the establishment of a board of experts to fix standards of food products. The secretary of the Board of Agriculture being authorized to fix such standards, with the advice of experts.

Sections 8 and 9 refer to the method of taking samples.

By section 10, the bill is not to be construed to interfere with the police regulations of any State or Territory.

Section 11 provides for the disposal of confiscated articles.

This bill does not interfere with any legitimate trade or industry, or prohibit the use of any product so long as that product has not been deemed injurious to health by an impartial commission. It does forbid interstate traffic in articles injurious to health. It also forbids improper branding. Any imitation or compound or mixture may be sold so long as it is distinctly and properly marked so that the purchaser or consumer shall be protected in his rights.

MASSACHUSETTS.—As this was one of the first States to adopt a general food act, with annual appropriations for its execution, the law is herewith quoted in full, with the principal amendments. Similar statutes have since been enacted in several other States.

ACT RELATING TO INSPECTION OF FOOD AND DRUGS.

Acts of 1882, 263, § 1.

No person shall, within this Commonwealth, manufacture for sale, offer for sale, or sell any drug or article of food which is adulterated within the meaning of this act.

Acts of 1882, 263, § 2.
Acts of 1886, 171.

The term "drug" as used in this act shall include all medicines for internal or external use, antiseptics, disinfectants, and cosmetics. The term "food" as used herein shall include confectionery, condiments, and all articles used for food or drink by man.

Acts of 1882, 263, § 3.
Acts of 1884, 289, § 5.
Acts of 1884, 289, § 7.

An article shall be deemed to be adulterated within the meaning of this act—

(*a*) In the case of drugs—(1) If, when sold under or by a name recognized by the United States Pharmacopœia, it differs from the standard of strength, quality, or purity laid down therein, unless the order calls for an article inferior to such standard, or unless such difference is made known or so appears to the purchaser at the time of such sale; (2) If, when sold under or by a name not recognized in the United States Pharmacopœia but which is found in some other pharmacopœia, or other standard work on *materia medica,* it differs materially from the standard of strength, quality, or purity laid down in such work; (3) If its strength or purity falls below the professed standard under which it is sold.

(*b*) In the case of food: (1) If any substance or substances have been mixed with it so as to reduce, or lower, or injuriously affect its quality or strength; (2) If any inferior or cheaper substance or substances have been substituted wholly or in part for it; (3) If any valuable constituent has been wholly or in part abstracted from it; (4) If it is an imitation of, or is sold under the name of, another article; (5) If it consists wholly or in part of a diseased, decomposed, putrid or rotten animal or vegetable substance, whether manufactured or not, or, in the case of milk, if it is the produce of a diseased animal; (6) If it is colored, coated, polished, or powdered, whereby damage is concealed, or if it is made to appear better or of greater value than it really is; (7) If it contains any added poisonous ingredient or any ingredient which may render it injurious to the health of a person consuming it.

The provisions of this act shall not apply to mixtures or compounds recognized as ordinary articles of food or drinks, provided that the same are not injurious to health, and are distinctly labelled as mixtures or compounds. And no prosecutions shall at any time be maintained under said act concerning any drug the standard of strength or purity whereof has been raised since the issue of the last edition of the United States Pharmacopœia, unless and until such change of standard has been published throughout the Commonwealth.

Acts of 1882, 263, § 5.
Acts of 1886, 101, § 4.

The State board of health shall take cognizance of the interests of the public health relating to the sale of drugs and food and the adulteration of the same, and shall make all necessary investigations and inquiries in reference thereto, and for these purposes may appoint inspectors, analysts, and chemists, who shall be subject to its supervision and removal.

Within thirty days after the passage of this act the said board shall adopt such measures as it may deem necessary to facilitate the enforcement hereof, and shall prepare rules and regulations with regard to the proper methods of collecting and examining drugs and articles of food.

Acts of 1891, 319, § 1.

For the purpose of carrying out the provisions of chapter two hundred and sixty-three of the acts of the year eighteen hundred and eighty-two, relating to the adulteration of food and drugs, the State board of health may expend annually a sum not exceeding eleven thousand five hundred dollars: *provided, however,* that not less than three-fifths of said amount shall be annually expended for the enforcement of the laws against the adulteration of milk and milk products.

Acts of 1882, 263, § 6 (see also 1886, 318, § 1).

Every person offering or exposing for sale, or delivering to a purchaser, any drug or article of food included in the provisions of this act, shall furnish to any analyst or other officer or agent appointed hereunder, who shall apply to him for the purpose and shall tender to him the value of the same, a sample sufficient for the purpose of the analysis of any such drug or article of food which is in his possession.

Acts of 1882, 263, § 7.

Whoever hinders, obstructs, or in any way interferes with any inspector, analyst, or other officer appointed hereunder, in the performance of his duty, and whoever violates any of the provisions of this act, shall be punished by a fine not exceeding fifty dollars for the first offence, and not exceeding one hundred dollars for each subsequent offence.

Acts of 1884, 289, § 2.
Acts of 1886, 101, § 4.

The State board of health shall report annually to the legislature the number of prosecutions made under chapter two hundred and sixty-three of the acts of eighteen hundred and eighty-two, and an itemized account of all money expended in carrying out the provisions thereof.

Acts of 1884, 289, § 8.

Before commencing the analysis of any sample the person making the same shall reserve a portion which shall be sealed; and in case of a complaint against any person the reserved portion of the sample alleged to be adulterated shall upon application be delivered to the defendant or his attorney.

The principal amendment to the foregoing act was that of 1897, wherein the section relating to labels was amended as follows:

"The provisions of this act shall not apply to mixtures or compounds recognized as ordinary articles, or ingredients of articles of food, if every package sold, or offered for sale, is distinctly labelled as a mixture or compound, *with the name and per cent. of each ingredient therein,* and if such mixtures or compounds are not injurious to health."

Other and special statutes have since been enacted in Massachusetts relating to special articles of food, such as that of 1897 relative to canned goods, and to molasses and syrups, and the more recent statutes of 1901 relating to labels and to the use of preservative.

The following summary presents in a condensed form some of the results of the work of food and drug inspection in Massachusetts by the State board of health during the past eighteen years of its work in this direction:

Summary.	1883.	1884.	1885.	1898.	1899.	1900.	18 years, 1883–1900.
Number of samples of milk examined	218	1,123	2,219	6,247	6,186	6,232	63,616
Number of samples above standard	35	347	1,297	4,307	4,506	4,431	39,364
Number of samples below standard	183	776	922	1,940	1,680	1,801	24,252
Percentage of adulteration	83.9	69.1	41.7	31.1	27.2	28.9	38.1
Number of samples of other kinds of food (not milk)	477	839	1,552	3,738	3,069	3,132	42,725
Number of samples of good quality	328	432	883	3,238	3,615	2,670	34.744
Number of samples adulterated, as defined by the statutes	149	407	669	500	454	462	7,981
Percentage of adulteration	31.2	48.5	43.1	13.4	14.8	14.2	18.7
Number of samples of drugs examined	603	682	1,007	812	547	758	11,173
Number of samples of good quality	357	431	571	531	303	377	7,016
Number of samples adulterated, as defined by the statute	246	251	436	281	244	381	4,157
Percentage of adulteration	40.8	36.8	43.3	34.6	44.6	50.2	37.2
Total examinations of food and drugs	1,298	2,644	4,778	10,797	9,802	10,122	117,514
Total examinations of good quality	720	1,210	2.751	8,076	7,424	7,478	81,124
Total examinations not conforming to the statutes	578	1,434	2,027	2,721	2,378	2,644	36,390
Percentage of adulteration	44.5	54.2	43.7	25.2	24.3	26.1	31.0
Expense of collection, examination, and prosecution	$2,931.56	$5,529.60	$8,557.43	$11,062.68	$11,251.83	$11,108.73	$172,947.91
Expense of collection, examination, and prosecution, per sample	2.26	2.09	1.79	1.02	1.15	1.10	1.47

In the foregoing table the first three columns of figures present the general statistics of the first three years' work; the next three columns give the figures of the last three years, and the final column presents the summary of eighteen years.

As is customary under the operation of all new laws of similar character, the first few months of work are usually devoted to an examination of the different sorts of food, in order to determine the extent and the character of adulteration. This preliminary examination established the fact that many staple products are not subject to adulteration, except in rare and isolated instances. This applies, so far as Massachusetts is concerned, to sugar, flour, and the various other cereal products, so that it has not been deemed necessary to give much attention to these articles of food. Hence the figures in the foregoing table should not be understood as representing the actual amount of adulteration existing in the general food supply, nor even in articles liable to adulteration, since special pains are taken at times to obtain only such articles as are known to be adulterated. Experience often shows an inspector where to find adulterated articles of food. The difference in the percentages of the first three years (1883, 1884, and 1885) and the last three (1898, 1899, and 1900) in the foregoing table may be taken as representing quite fairly the improvement, not in the general food supply under the present inspection, but in those articles which are found to be liable to adulteration. Upon this point the board published the following general statement in its Annual Report of 1884:

"There can be no question as to the beneficial results of the law, as executed by the officers of the board, in improving the quality of the food and drug supply of the State, especially in regard to milk and butter—in the former case as relates to the quality of the supply, and in the latter as relating to the proper branding and marking of spurious goods. The extensive correspondence of the Health Department with wholesale houses outside of Massachusetts also confirms their appreciation of the value of the work done in this State, and also the necessity of furnishing articles of undoubted purity for this market. This is especially true of all classes of drugs sold at wholesale by parties outside the State.

"The actual economic results obtained by the enforcement of the statutes relative to food and drug inspection cannot be stated exactly. The law is comprehensive and its provisions cover a great variety of articles. Its restraining influence extends outside of the State to manufacturers sending goods to this market. It is specially provided by the statute that at least three-fifths of the amount appropriated shall be expended in the enforcement of the laws relating to the adulteration of milk and its products. This provision has been carefully observed."

It was found convenient, after a year's work, to adopt a code of regulations for the government of its analysts and inspectors in the performance of their duties under the Food and Drug Acts. The following is a copy of these regulations.

Rules and Regulations of the State Board of Health of Massachusetts Relative to the Inspection and Analysis of Food and Drugs.—1. The State board of health shall appoint analysts and inspectors, as provided in section 5 of chapter 263, Acts of 1882.

2. It shall be the duty of the inspectors to procure samples of drugs and articles of food at such times and places as the secretary shall direct, in the manner provided in section 6 of chapter 263 of the Acts of 1882, and in section 3 of chapter 289 of the Acts of 1884, and in all acts amendatory of said provisions.

3. Under the direction of the secretary, the inspectors shall, for the identification of samples, affix a number to each sample of food or drugs obtained by them, in such manner as may be prescribed. Under no circumstances shall an inspector convey any information to an analyst as to the source from which any sample was obtained.

4. The inspectors shall keep records of each sample, each record to include the following items: (*a*) The inspector's number; (*b*) the date of purchase or receipt of sample; (*c*) the character of the sample; (*d*) the name of the vendor; (*e*) the name of the city or town, and street and number where the sample is obtained, and, in the case of a licensed milk pedler, the number of his license; (*f*) as far as possible the names of manufacturers, producers, or wholesalers, with marks, brands, or labels stamped or printed upon goods.

5. It shall be the duty of the analysts so appointed to determine, under the direction of the secretary, by proper examination and analysis, whether articles of food and drugs, manufactured for sale, offered for sale, or sold within this Commonwealth, are adulterated within the meaning of chapter 263 of the Acts and Resolves passed by the General Court of Massachusetts in 1882, and all acts amendatory thereof, adulteration being defined as follows, viz.: (Here follows a statement of the statute as already given in a previous page.)

6. It shall also be the duty of the analysts to receive such specimens of food and drugs for analysis as may be delivered to them by the secretary, or by the inspectors,

and to examine the same. To avoid, as far as possible, all suggestion or danger of specimens having been tampered with, each analyst shall keep each specimen in his possession in a suitable and secure place, labelled in such a manner as to prevent any person from having access to the same without the knowledge and presence of the analyst.

Analyses of perishable articles should be made promptly after they are received.

7. An analyst shall give no information, under any circumstances, regarding the result of any analysis, to any person except to the secretary of the board, prior to any trial in court in reference to such analysis.

The analysts shall carefully avoid any error regarding the inspector's number attached to each sample, and shall report the results of their work in detail to the secretary.

In the case of all articles having a numerical standard provided by statute, the result of the analysis should show their relation to such standard.

8. Before beginning the analysis of any sample, the analyst shall reserve a portion, which shall be sealed, and in the event of finding the portion analyzed to be adulterated, he shall preserve the sealed portion, so that in case of a complaint against any person the last-named portion may, on application, be delivered by the secretary to the defendant or to his attorney.

9. Each analyst shall present to the secretary, on the Monday before the first Thursday of each month, a summary of the analyses made by him during the previous month.

Each analyst shall also present, on or before the first of January of each year, an annual report of the work done for the year ending on the 30th of September preceding.

10. The secretary shall have charge of the reports of analyses, and shall cause cases founded on such reports to be submitted to the courts for prosecution.

In each case of a retailer, and of every dealer not a manufacturer or producer, he may, if the party has not been previously complained of in court, issue a notice or warning of any violation of the law relative to the adulteration of food and drugs, and of the offender's liability to prosecution on a repetition of the sale.

11. Should the result obtained by any analyst be questioned in any given case, another analyst shall repeat the analysis, unless otherwise instructed by the board, provided a sufficient sum to meet the expense of the analysis be deposited with the secretary by any interested party feeling aggrieved, which sum will not be returned unless the second analysis fails to confirm the first in essential particulars.

12. Any appeal from the decision of an analyst shall be filed with the secretary, who shall report it, and any matter in controversy to the board, giving his judgment thereon, and the board shall supervise and control the action of its officers in executing the law.

13. Where standards of strength, quality, or purity are not fixed by the act, the analysts shall present to the secretary such standard as in their judgment should be fixed, and the secretary shall report the same to the board for its action. The standards set by the British Society of Public Analysts will be followed, as nearly as practicable, until otherwise ordered.

14. Whenever a drug or preparation, not prescribed in a national pharmacopœia or other standard work on materia medica, shall be manufactured, offered for sale, or used in this State, the standard of such drug, and the standard and proportion of the ingredients of such preparation, and the range of variability from such standard or standards, shall be ascertained by the analysts, who shall report the same through the secretary to the board.

15. The analysts shall occupy such time in the performance of their respective duties as a reasonable compliance with the terms of the statute shall require, and shall be present one hour of each day, at such time of the day and at such place as shall be designated by the board, to meet the convenience of interested parties and the public.

The following classified list embraces most of the examinations of articles of food examined in Massachusetts under the Food and Drug Acts up to October 1st, 1898:

Articles examined.	Total examined.	Number adulterated or below standard.	Per cent. of adulteration.
Milk	51,198	20,771	40.6
Condensed milk	247	21	8.5
Butter	3,563	413	11.6
Cheese	473	1	0.2
Vinegar	1,750	927	53.0
Lard	450	126	28.0
Olive oil	524	257	49.0
Spices and condiments	14,902	2,674	17.9
Coffee	1,088	245	22.6
Tea	976	31	3.2
Cocoa and chocolate	208	53	25.5
Wheat flour	167	5	3.0
Bread and cake	86	1	1.2
Cornmeal and other cereals	18	0	.0
Sago, tapioca, and corn starch	21	0	.0
Cream of tartar	4,486	465	10.4
Soda and saleratus	100	2	2.0
Molasses	2,394	305	12.7
Syrups	122	56	45.9
Maple syrup	483	135	28.0
Maple sugar	365	87	23.8
Sugar	156	9	5.7
Honey	716	209	29.2
Confectionery	784	65	8.3
Pickles	29	2	7.0
Lime juice and lemon juice	28	21	75.0
Horseradish	20	8	40.0
Arrowroot	21	4	19.0
Gelatin	34	3	9.0
Salt	21	1	4.8
Canned food *	523	244	46.6
Flavoring extracts	39	5	12.8
Sardines	5	4	80.0
Jellies and jams	112	47	42.0
Spirits, wine, ale, beer and cider †	192	121	63.0
Miscellaneous ‡	1,493	523	35.0
Drugs	9,898	3,532	35.7

* A considerable portion of these were French vegetables, which were examined for the presence of copper as a coloring agent.

† A large number of examinations of spirits and wines is included in the item of drugs.

‡ Under this head are included samples of sage, marjoram, macaroni, vermicelli, poultry dressing, desiccated cocoanut, citron, compressed yeast, meat extracts, cooking utensils, food wrappers, wall paper, clothing and textile fabrics, bottle stoppers, food preservatives, coloring matter, etc.

A broad view of the subject of food inspection would include the examination of water as one of the necessaries of life, since it is essential to the preparation of most articles of food, and also a convenient vehicle for the administration of very many of them. It is also absolutely necessary to the healthy growth of the human organism.

The important work of water analysis has been conducted by the Engineering Department of the State board of health since 1887, and this work has been extended to the examination of the waters of the ponds, streams, springs, reservoirs, and wells used as public supplies by about 160 cities and towns in the State. The total number of such examinations has been about 30,000. Full reports upon this subject may be found in the reports of the board for the years 1887 to 1900, and in the special document upon the examination of water supplies published in 1890.

In addition to the regular routine mode of food and drug inspection in Massachusetts, much has been accomplished by work in special directions during the eighteen years since the work was begun. These may be enumerated as follows:

Investigations relating to the *quality of milk* as produced by the cow.

Analysis of Injurious and other Empirical Preparations.—Hair dyes, cosmetics, bitters, and tonics; alleged cures for the opium and alcohol habits, catarrh and asthma cures containing cocaine, etc.

Coloring Matters in Food.—Milk, butter, oleomargarine, preserved vegetables, salts of tin in molasses, etc.

Food preservatives; the quality of *wines and liquors;* report upon *oleomargarine;* the uses of *glucose* in food; the presence of *trichinæ* in pork products; the standard of *vinegar;* the use of the word "*compound,*" etc.

The Standard of Milk.—For the purpose of determining the consistency of the existing standard of milk in Massachusetts, analyses were made in 1884 of the milk of six hundred cows, the samples being collected in different parts of the State, and from different herds of animals, of different ages, and in different seasons of the year. The average total solids of the entire number was found to be very nearly thirteen and one-third per cent. (the legal standard of Massachusetts is thirteen per cent. in winter, and twelve per cent. in summer). In later years these figures have been confirmed by further examinations upon the same point.

With reference to breeds of cows the results of analyses were as follows:

The average milk of 11 Jerseys had 14.02 total solids and 4.34 fat.
" " " " 92 native cows " 13.09 " " " 3.31 "
" " " " 30 Ayrshires " 12.97 " " " 3.35 "
" " " " 51 Durhams " 12.73 " " " 3.28 "
" " " " 47 Holsteins " 12.51 " " " 3.29 "

Artificial Coloring Matter in Food.—The practice of employing coloring matters in connection with different articles of food is very common. The following may be named as very common examples:

Certain condiments, such as mustard, ginger and other spices, sugar, confectionery, preserved and canned goods (especially peas, beans, and tomatoes), milk, butter, oleomargarine, pickles, cake, syrups, jellies, jams, preserves, fruit syrups, flavoring extracts, and various sorts of beverages.

The coloring matters employed in connection with these articles of food may be classified as follows:

1. *Harmless Colors.*—These are usually made from some comparatively harmless organic products, such as annatto, caramel, turmeric, and cochineal. Aniline dyes, the products of coal tar, are also quite largely used for the coloring of milk, jellies, jams, preserves, and other articles of food.

2. *Injurious Colors.*—These are usually some of the metallic compounds, such as lead, copper, and tin.

It cannot be urged in regard to any of these colors, whether harmless or otherwise, that they have any true value as articles of food, and the demand for their use comes mainly from the trader, and not from the actual consumer, excepting, so far as the latter has been erroneously educated by the former as to color standards in the matter of food. No good and useful end is attained by their use, so far as the question of nutriment is concerned, and not only may harm ensue, but also even fatal consequences.

The use of artificial food colors is usually a fraudulent one, and they are consequently employed mainly for the purpose of giving to an inferior article of food a fictitious value, and thus to imitate other articles of a similar character, but of better quality, at least so far as their actual cost is concerned. The difference in actual nutritive value as articles of food may, however, be but little or nothing.

When examinations of milk were made in Massachusetts soon after the enactment of the law of 1882, it was found that the addition of coloring matter to milk was a very common practice in the cities. From the fact that colored samples of milk were almost invariably found to be adulterated in other ways, it was inferred that artificial coloring was practised for the purpose of concealing fraud, and of giving to milk which had been skimmed and watered the appearance of milk of good standard quality. Hence a vigorous warfare was made against the practice until it disappeared.

The question of the sale of preserved vegetables colored bright green by sulphate of copper came to the attention of the board, and the safe ground was taken that the introduction of poisonous metallic colors in any amount whatever should have no legitimate place in the food-supply of the people. A general law forbidding the use of any sort of coloring matter in food would diminish the amount of food adulteration very decidedly.

Trichinæ in Pork.—Among the many questions relating to the food supply in Massachusetts the quality of the pork offered for sale has not been overlooked. Nearly thirteen thousand hogs have been examined under the direction of the board for the presence of trichinæ. Of this number 791, or 6.3 per cent., were found to be trichinous. Western hogs were found to contain less than Eastern, and of those raised in Massachusetts, those reared in public institutions and upon the refuse of cities were found to suffer the most. An examination was also made of sausages, and only one out of 365 was found to contain trichinæ.

Baking Powders.—No class of substances employed in the preparation of food has been the subject of so much discussion as these; and this is true notwithstanding the fact that, as elements in the matter of food economy, or as nutritive constituents of the necessary food of mankind, they have absolutely no value. Their use in the preparation of food was unknown until the early part of the present century, and for ages the human race thrived without them. Whenever bread was desired which should possess the properties of porosity and lightness of texture, in early times, some sort of leaven or yeast was employed for the purpose.

The use of baking powders at the present day is due, undoubtedly, to several causes, prominent among which is a demand for rapid and convenient methods of preparing bread and pastry for cooking; and, also, to the stimulus of trade produced by excessive advertising.

If the statements of rival manufacturers as to the poisonous qualities of all other baking powders except their own were to be credited, the use of these preparations would soon cease. Such false teaching does harm in misleading the community and creating a distrust. The fallacy lies partly in the want of discrimination between large and small doses of the ingredients of such powders. For example, common salt and mustard act as poisons in large doses and produce vomiting. In small doses, on the contrary, neither of them is harmful. Again the process of cooking changes the character of all baking powders.

It should be remembered that the introduction of these articles is of comparatively recent date; that they are compounded of several ingredients; that different manufacturers employ different ingredients to attain the same object or end, and, except in a few instances, standards of purity have not been adopted for this class of articles: hence the use of the terms *purity* and *impurity,* as applied to them, must be considered as arbitrary, or at least merely conventional. Experiments have been undertaken with the view of settling the question as to whether the ingredients of certain baking powders were injurious to health; and, while positively harmful results have in some instances been reached by the ingestion of considerable doses of such ingredients, when taken singly, still, the question of actual injury to the health of human beings on the one hand, or of freedom from harm on the other, from the use of baking powders in food, cannot be regarded as settled.

Intoxicating Liquors and Beverages.—The examinations of intoxicating liquors (including those of wines, ale, and beer), which have been made by the chemists of the board, have embraced samples which have been obtained both as drugs and as beverages, the former having been obtained exclusively from drug-stores, and the latter from places where such articles are retailed as beverages.

These examinations have shown that while adulteration of intoxicating liquors is a matter of very common occurrence, the presence of harmful adulterations, contrary to popular opinion, is rare. The following statement of the analyst in the report of 1886 is also confirmed by more recent examinations.

"For the sake of the public health, it is a cause for congratulation that the chief deviations from the requirements of the Pharmacopœia consist almost exclusively in the addition of alcohol, of water, and of harmless sweetening and flavoring substances. Not a single sample of adulterated spirits in the popular understanding of that term, that is, one containing a more injurious ingredient than alcohol itself, was met with, although very few were exactly what they purported to be" ("Supplementary Report of Health Department, Mass.," 1886, p. 184).

Mixtures or Compounds.—The work of inspection includes a careful examination of the methods in which food is offered for sale, especially with reference to the question of labelling and the agreement of the label with the actual contents of the package to which it is affixed, since the statute of Massachusetts provides that "mixtures or compounds" are not to be treated as adulterated in the eye of the law, "provided that the same are not injurious to health and are distinctly labelled as mixtures or compounds with the name and per cent. of each ingredient therein."

This provision of the law is frequently disregarded, especially in the case of spices; and while the term "compound" is to be found after prolonged search upon the label, it often occupies an obscure position, or is printed in extremely small type, so that the term "*distinctly* labelled" does not apply.

It is not always safe to infer that all parts or packages in a lot of spices or similar articles of food are pure, because a single sample or package proves to be pure. The following case is an illustration: Two packages of powdered cloves were obtained at a grocery. The packages were in unbroken tin boxes of one-quarter pound each, and were purchased at an interval of three weeks; each package was of the same size, and each had exactly the same brand or label. On inquiry of the retailer it was found that both of the packages came from the same lot. It appeared on examination that the first package was considerably adulterated and the second was pure. A notice of this fact was therefore sent as usual to the retailer, who transmitted the notice to the manufacturer, who lives outside the limits of the State; he denied the charge, and hence, as is customary in cases of disputed analysis, samples were sent to a second analyst, who confirmed the statements of the first; and finally, four analyses were made with the same result, neither chemist knowing anything of the source of the samples, nor did either know that a previous analysis had been made.

This circumstance shows that it is not always safe to judge of the character of any group or lot of articles from the examination of a single sample.

Gross Appearances.—It is evident that very little reliance can be placed upon the mere external inspection of articles of food, such as may be made by the employment of the senses of taste, touch, smell, and sight, since the principal object of the falsifier of food preparations is to deceive the senses of the consumer by every possible resource of his art. It is a common experience in this department of work to receive articles of food from various sources, which are believed by the persons presenting them for examination to be adulterated, but which the analyst finds to be pure. This experience is true in the case of many of the articles of food which are liable to adulteration, and also of some articles which are scarcely ever found to be adulterated. The same experience has been met by other authorities who have had charge of similar work ("Report of Commissioner of Internal Revenue," Washington, 1887, p. cxliii.). Among the various articles which have been thus submitted to the board for examination (under the impression of the person submitting them that they were adulterated) were the following: Flour, sugar, molasses, vinegar, cream of tartar, honey, milk, butter, cheese, lard, salt, and several kinds of spices or condiments.

The reasons for these false notions with reference to the quality of articles of food are mainly the following: 1. A liability to mistake the deterioration of an article, or an inferiority in grade or quality, for an actual falsification or substitution. 2. A lack of familiarity with the true physical characteristics of the article in question.

Notices to Retailers.—It has been the custom of the board to issue a warning notice to retailers selling articles found to be adulterated, in cases in which there was a reasonable probability that the retailer was not aware that such articles were adulterated.

In certain articles of food which have been specially liable to fraud, such as the various sorts of spices, condiments, cream of tartar, etc., adulteration has been greatly diminished, and is in many instances limited to parties whose business is conducted outside of the State, and cannot therefore be easily reached except through the customary notice sent to the retailer who buys of such outside parties.

These notices have proved to be a very efficient mode of diminishing adulteration. It is not the retailer who is seriously affected by the receipt of such a notice, but the wholesale dealer or manufacturer to whom it is speedily forwarded by the retailer, and who finds that he cannot afford to continue a wholesale imposition.

In the following table the ratio of adulteration found in articles of food and drugs examined in England and in Massachusetts during the period of inspection and enforcement of the laws is presented:

PERCENTAGE OF ADULTERATION AS GIVEN IN THE REPORTS OF EACH YEAR.

Year.	England and Wales.		Year.	Massachusetts.
	Ratio of adulteration. Per cent.	Average five years. Per cent.		Ratio of adulteration. Per cent.
1877	19.2	16.2		
1878	17.2			
1879	14.8			
1880	15.7			
1881	14.7			
1882	15.1	13.9		
1883	15.0		1883	44.5
1884	14.4		1884	54.2
1885	13.2		1885	42.4
1886	11.9		1886	38.7
1887	12.8	12.7	1887	34.3
1888	10.8		1888	30.3
1889	11.5		1889	31.9
1890	11.2		1890	31.5
1891	12.2		1891	32.8
1892	12.4		1892	33.7
1893	12.9		1893	31.2
1894	10.3		1894	31.9
1895	9.3	10.8	1895	38.5
1896	9.2		1896	26.6
1897	9.4		1897	24.8
1898	8.7		1898	25.2
			1899	24.3
			1900	26.1

As a comment upon the foregoing table and the diagram below the following observations may be made:

First. The gradual lessening of adulteration under the action of judicious legislation.

Second. The much greater ratio presented in the column headed Massachusetts than in that of England and Wales. The reason for this great difference may be found, *first*, in the fact that in conformity to the requirements of the statutes in Massachusetts more than half the samples examined were milk. The standard of milk in the State is unusually high as compared with that of other countries (thirteen per cent. of solids, in winter, and twelve per cent. in summer). Hence it is the custom to report all samples as adulterated which are found to be below the foregoing limits. Now, there are many animals, especially those of the Holstein breed, which habitually produce milk having less than thirteen per cent. of solids. Hence it has not been deemed prudent to enter complaints at court to the full extent of the legal requirements. In the case of milk, therefore, the ratio of adulteration as reported is for the most part an apparent and not an actual adulteration. *Secondly*, the samples selected under the Massachusetts law are mainly such as are known or suspected to be adulterated, while in England many samples of such staple articles as bread, flour, sugar, and tea are annually examined, which are practically free from adulteration.

A prominent feature in the execution of the Massachusetts law is that of expenditures. The sum appropriated for the work of the first year was $3,000; of the second year, $5,000; of the third year, $10,000, and for the past nine years, ended 1901, it has been $11,500 per year. About $35,000 has been collected since and including 1888 in fines for violation of the law, this amount being returned to the treasuries of cities, towns, and counties.

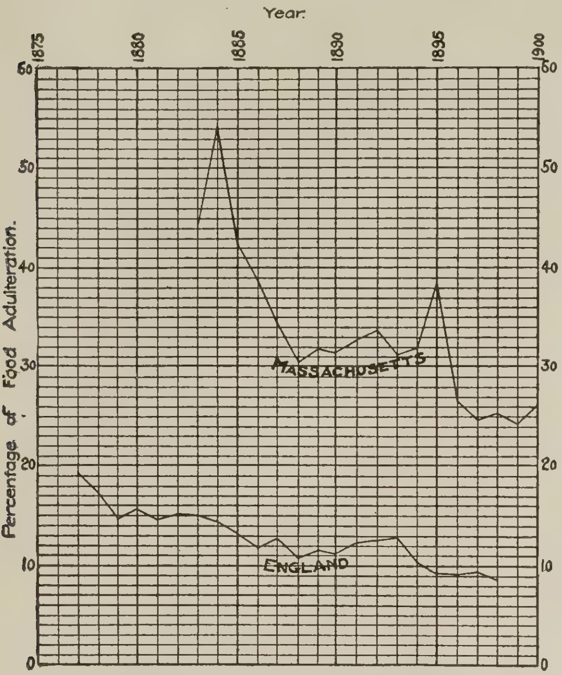

FIG. 2098.—Diagram showing the Ratio of Adulteration in England, 1877–1898, and in Massachusetts, 1883–1900.

Small amounts were expended annually at first for legal services, the entire amount for the first twelve years being $1,639.63, or less than $150 per year. But for the past six years, no expenses whatever have been incurred in the employment of counsel, the inspectors having become familiar with the methods of presentation of cases at court.

The annual ratio of samples of food collected for examination to the whole population in recent years has been as follows:

In England and Wales (1895–99)......	about	1	to each	700	inhabitants.
In Paris (1895–99).....................	"	1	"	100	"
In Massachusetts (1895–99)...........	"	1	"	250	"
In Ohio (1898) (612 samples).........	"	1	"	6,635	"
In Connecticut (1898) (1,265 samples).	"	1	"	665	"
In New Jersey (1899) (1,792 ").	"	1	"	1,026	"
In Minnesota* (1897-98) $\frac{1582}{2}$ = (791 samples)	"	1	"	1,062	"
In New York (1895) (2,391 ")	"	1	"	2,774	"

CONNECTICUT.—Acting under the provisions of a Law of 1895, the Connecticut Agricultural Experiment Station makes analyses of "food products on sale in Connecticut suspected of being adulterated," and is provided with an annual appropriation of $2,500 for this purpose. The station also examines food products submitted by the Dairy Commissioners.

During the year 1898, the number of samples thus examined, exclusive of cattle feeds, was 1,265. The principal articles examined were as follows:

Jellies.—Seventy samples, 43 adulterated, the chief adulterants consisted of gelatinous materials (starch, paste, gelatin, agar-agar, and apple jelly), sweetness (glucose, and saccharin). Saccharin costs $15 per pound, but is 500 times as sweet as sugar. It has no nutritive qualities. Coloring matter (mostly aniline dyes); fruit flavors, acids, and chemical preservatives. The report publishes the name of the brand and wholesale dealer and of the retailer in each case, also the place of sale, quantity, and price.

Of 51 samples of jams, preserves, and marmalades 45 were found to be adulterated, the principal adulterants were glucose, salicylic acid, and aniline or other artificial colors.

Tea.—Eighty-nine samples were examined and "none of the samples were found adulterated other than by facing."

Coffee.—Of 73 samples 11 were found adulterated, or 11 out of 45 to which the statutes would apply.

The percentage of adulteration of coffee in the past three years was as follows: 1896, 63.3 per cent.; 1897, 57.7, and in 1898, 24.4. This improvement the board attributes to the operation of the pure food law.

Ginger.—Ninety-one samples were examined, 24 adulterated.

Ale and Beer.—In 47 samples 12 were found to contain salicylic acid.

Sausage.—Of 19 samples 14 contained borax and 10 contained starch.

Honey.—Of 37 samples of honey the report says "five are probably pure, 22 may be genuine, though they seem to be made by bees fed somewhat with cane-sugar, or to have had invert sugar added to them; 2 unquestionably contain cane-sugar added as an adulterant, and 8 are adulterated with glucose syrup."

Examinations of milk, cream, maple syrup, mince meat, and canned vegetables failed to find any adulterations worthy of note.

Of 332 samples of spices in bulk and 242 samples in packages examined in the three years (1896–98) 41.5 per cent. of the former and 23.5 per cent. of the latter were adulterated.

The report recommends as the only safe course in buying spices, that they should be bought in "sealed packages, bearing the name of a reliable house whose goods have not been found adulterated."

Of 203 samples of molasses, 34 were found to be adulterated with glucose.

OHIO.—The Dairy and Food Commission of Ohio reports upon the examination of 612 samples of food examined in 1898, of which 292 or 47.7 per cent. were adulterated.

The principal articles examined were 31 samples of flour of which 4 were adulterated; 15 of maple syrup, 7 adulterated; 110 of milk, 31 adulterated; whiskey 54, of which 27 (or one-half) were adulterated; spices, 18, of which only one, a sample of cinnamon, was adulterated; wine 6, all pure; flavoring extracts, 17, of which 8 were adulterated; cream of tartar 6, of which 1 was adulterated; cheese 4, all genuine.

The number of prosecutions instituted was 68, of which 14 were for adulteration of milk, 33 for butter, and 5 for whiskey.

$2,064.40 was collected in fines and fees. About $8,000 was expended for legal services.

NEW JERSEY.—The Dairy Commission of New Jersey reports for the year 1899 that 1,792 samples of food were examined. Of these 712 were samples of milk, 959 butter and oleomargarine, 46 linseed oil, 46 condensed milk.

Six hundred and three of the milk samples were above the standard of 12 per cent. solids. Fifty of the samples purchased as butter proved to be oleomargarine; the remainder were pure butter.

Only five samples of milk contained formalin.

Five samples of linseed oil out of 46 were adulterated.

$3,050 were collected in fines.

MINNESOTA.—The Dairy and Food Commissioner of Minnesota, in his biennial report for the two years ended July 31st, 1898, presented the operations of his department under the dairy and food laws of the State. In addition to the general statutes relating to inspection of dairy products, other special laws have been enacted in

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* Biennial Report.

Minnesota for the prevention of adulteration of honey, confections, jellies, spices, and condiments.

The whole number of samples of food examined in the two years was 1,582, of which 807, or 51 per cent., were adulterated. The principal articles examined were as follows:

Vinegar,	807	samples, of which	466	were adulterated.	
Baking powder,	175	" " "	131	" "	(alum).
Butter,	26	" " "	4	" "	
Cheese,	148	" " "	18	" "	
Cream of tartar,	2	" " "	2	" "	
Hominy,	32	" " "	8	" "	
Spices,	162	" " "	26	" "	
Jelly and jam,	28	" " "	15	" "	
Lard,	84	" " "	34	" "	

New York.—The State board of health of New York, in its fifteenth annual report (1895), presents the statistics of 2,391 samples examined during the year. Nearly all of these were drugs, which the chemist classified as follows:

Of good quality	1,307,	or 57.1	per cent.
" fair quality	284,	" 12.4	" "
" inferior quality	598,	" 26.1	" "
Not as called for	41,	" 1.8	" "
Excessive strength	59,	" 2.6	" "
Total drug samples	2,289		

The principal articles examined were 230 samples of ether, of which 114 were not of standard quality.

Compound spirits of ether, 109 samples examined, of which only 35 were of good quality.

Hydriodic acid, 127 samples, of which 111 were of good quality.

Dilute hydrochloric acid, 105 samples, of which 71 were of good quality.

Tincture of iodine, 205 samples, of which only 39 were of good quality.

Magnesia, 149 samples, of which 65 were of good quality.

Diluted phosphoric acid, 162 samples, 126 of good quality.

Aromatic sulphuric acid, 120 samples, only 9 of which were considered to be of good quality.

Precipitated sulphur, 104 samples, 38 of good quality.

Fifty-nine samples "contained large quantities of sulphate of lime."

The chemist also examined 102 samples of canned tomatoes, to determine whether they contained artificial coloring matter. Only 2 samples were found to be colored with eosin.

In the seventeenth report of the board, the director of the laboratory states: "Through lack of funds available for the purpose, the systematic collection and examination of food and drugs was suspended June 1st, 1895."

In Indiana the State board of health has been authorized "to prepare rules and ordinances, where and when necessary, regulating minimum standards for food and drugs, defining specific adulteration, and determining the proper methods of collecting and examining drugs and articles of food." Under this provision the board has published standards for the following articles of food:

Milk, butter, margarin, cheese, coffee, tea, candy, cider, flour, jellies and preserves, honey, lard, molasses and syrups, olive oil, spices, vinegar, baking powders, and spirituous liquors and wines. The use of preservatives is also regulated. Milk must contain no added coloring matter nor preservative. It must not be sold if taken within ten days after calving, or within twenty-one days before expected calving; nor must it be sold if taken from a cow fed with damaged food, or such as will impart a disagreeable flavor. It must not be taken from a sick or diseased cow, nor from one to which polluted water has been given, nor from one which has been "kept under conditions contrary to the rules of the State board of health governing dairies."

Classification of Work.—The work of a food analyst embraces a variety of branches. In a recent monograph by two French army surgeons, Polin and Labit, the following classification of such work is presented. Three principal groups, as follows: 1. Examination of articles in which the alterations in character are either of a chemical or of a mechanical kind. 2. Those which are biological. 3. Those which are parasitic.

The first group is subject to the following subdivision: (*a*) Additions have been made to the food products either of a commercial or a fraudulent nature, and of substances more or less harmful. (*b*) The vessel in which the food has been prepared or preserved renders the food poisonous. (*c*) The manipulation of food, or its surroundings, may expose it to harmful contamination. (*d*) It may be mixed accidentally with foreign substances.

The second group is subject to the following divisions: (*a*) An animal designed for food has been fed with food of a harmful or poisonous character; the poisons absorbed appear in the milk, or, not having had time to become eliminated, either the whole animal or some of its organs have become poisonous. (*b*) Recognizes the possibility of the formation of poisonous ptomaïns in meat, under certain conditions. (*c*) In consequence of certain unknown conditions wholesome vegetable food occasionally becomes harmful.

Third group: (*a*) Animal, vegetable, and mineral food products may be invaded by parasites of the larger kinds. (*b*) Food may become the prey of micro-organisms of a parasitic nature, involving the processes of (1) fermentation, (2) putrefaction, and (3) the development of infectious diseases, either of which may render the food harmful, either by infection, by ptomaïn poisoning, or by the combined action of both. (*c*) Food contaminated by its surroundings, or by infectious contact, becomes the carrier of pathogenic germs.

This list is sufficiently ample to show that the food analyst has a wide field of investigation.

Regulations.—The following special regulations regarding food inspection were published by Dr. Schumacher Kopp, canton chemist of Lucerne, and also a member of the International Jury of Award at the Paris Exposition of 1889.

The following extract is taken from his report:

Collection of Food.—In collecting food the greatest cleanliness should be observed. Clean bottles, and, if possible, new ones, should be used in collecting fluids. Bottles should be closed only with new corks.

In collecting drinks, the local experts must be present, and the beverages should be drawn from the regular source of supply.

In collecting milk, fill the bottle to the cork; seal every bottle at once after corking it. If milk is collected in a stable, the cows must be milked quite dry, by a disinterested person, and in the presence of the local magistrate or a policeman.

Strong glass, or porcelain, or crockery vessels should be used for the collection of butter.

For coffee, tea, and meal, boxes of clean wood or pasteboard should be used.

The use of paper bags for collecting samples is forbidden.

Bread and sausages should be wrapped in clean white paper; if possible, parchment paper.

The use of printed or colored paper for this purpose is forbidden.

Quantity of Food Necessary for Examination.—1. For the local health authority: Beer, 1 litre; bread, one whole loaf; brandy, 0.3 litre; butter, 50 gm.; vinegar, 0.2 litre; coffee, 30 gm.; meal, 200 gm.; milk, 0.5 litre; cider, 0.5 litre; tea, 10 gm.; drinking-water, 1 litre; wine, 0.5 litre; small sausages, one whole sausage; large sausages, 100 gm.; honey, 50 gm.

For the canton chemist the quantities are nearly the same as the foregoing, but in most instances two samples are taken. When two samples are taken, for example, of water, 2 litres in one bottle are not meant, but two bottles each containing 1 litre.

Sealing.—The samples collected must be sealed at once upon the spot, with an official seal. This seal must cover the whole head of the bottle, in order to keep the air out and to avoid leakage.

Marking.—The samples should be plainly marked in two different places immediately after collection, one on the neck of the bottle, and the other on the opposite side of the body of the bottle. Each marking must contain: (1) The number and name of the article collected; (2) name of the jurisdiction authorizing the collection, and of the collector.

Provision is made for the collection of two samples when necessary, so that, in case of a dispute, the second may be examined under the auspices of a superior authority. The samples sent to the canton chemist must contain no information as to their source. A report must also be sent to the health officer, stating the articles collected, the date of their collection, name of the dealer, his source of supply, and in every case his remarks upon the character of his goods. This report must be signed by the local expert and by the police assisting in the collection. All samples sent to the canton chemist must be so packed with sawdust, paper, or wadding, that they may be transmitted without injury. The name of the sender must accompany all packages, letters, etc., and they must be prepaid; otherwise they will not be received.

In sending milk to the canton chemist, observe especially: 1. That the milk is thoroughly cooled in cold water before it is forwarded. 2. (*a*) In the accompanying report mention must be made first of the number of cows from which a sample of mixed milk is taken; (*b*) how many cows, if any, are in the stable which have calved within fourteen days of collection of the milk; (*c*) how many cows, if any, are near the time of calving.

FOOD STANDARDS.—*Bread.*—The water in a freshly baked loaf of bread should not be more than thirty per cent. of its weight, and the ash, after deducting the common salt, should not be more than one per cent.

Butter.—This name should be associated only with the fat which is made from milk only. Artificial butter must be properly marked as such, being designated as margarine, and packed in separate parcels. Such names as "cheap butter," "tub butter," and "Alpine butter," are forbidden, except as applied to pure butter.

Vinegar must contain four per cent. of acetic acid. The addition of other acids, flavoring matter, and aniline colors, is forbidden.

Honey must be called honey only when it is free from adulteration. Such terms as "table honey," "Swiss honey," and "Appenzell honey," etc., are forbidden, except when applied to pure honey. Substitutes for honey, such as syrups, etc., and also mixtures of these with pure honey, must be plainly marked as such.

Coffee must not yield more than four per cent. of ash (Mocha, eight per cent.). Artificial coloring is to be regarded as adulteration. Mixtures of coffee with other substances are not to be called coffee.

Rye meal should not yield more than two per cent. of ash.

Wheat meal should not yield more than one and a half per cent. of ash. The water of rye and wheat meal should not be more than fifteen per cent. of its weight, and that of other meals eighteen per cent.

Milk.—Milk must be sold as drawn from the cow. Its specific gravity at a temperature of 15° C. (60° F.) before skimming should not be less than 1.029 nor more than 1.033, and when skimmed after twenty-four hours it should not be less than 1.033 nor more than 1.037. The chemical examination should show at least 11.5 per cent. of solid residue, and at least three per cent. of fat.* When taking milk at dairies for comparison, it is desirable to have examinations made within the shortest possible time, three days at the longest, and the cows should be milked dry by disinterested persons. "Centrifugal" milk should be marked as such, and when inspected at a temperature of 15° C. should have a specific gravity of from 1.034 to 1.037, and should have at least 8.4 per cent. of solids. The sale of the milk of sick cows is forbidden, as well as that of cows within eight days before and after the time of calving.

Cider, after fermentation, must not have less than three per cent. by weight, and 3.76 per cent. by volume of alcohol, and not less than 1.5 per cent. of solids, nor less than 0.15 of one per cent. of ash.

Tea must not have more than seven per cent. of ash.

Water for domestic use must have neither color nor sediment. Nor should it have smell or bad taste. Water containing infusoria and bacteria should be avoided.

Sausages should be made only of healthy, fresh meat, fat, and spices in general use. Any additions of starches are considered as adulterants.

PROPRIETY OF INTERNATIONAL LAWS ON THE SUBJECT OF FOOD INSPECTION.—Dr. Von Hamel Roos expressed his opinion at the International Congress of Hygiene at London, in 1891, that a *codex alimentarius* should be adopted for civilized nations, as agreed upon by a competent commission for general use. He commented upon the different standards of different countries, and as an example quoted the milk standard of Massachusetts (which is thirteen per cent. of solids in winter and twelve per cent. in summer), while milk having 11.5 per cent. solids is deemed to be pure in Holland.

At the International Congress of Agriculture at The Hague, in the following month (September, 1891), conclusions were formulated as to the need of uniform laws relative to food adulteration and the protection of food products. It was then voted "that each State should establish a commission of competent men, who should be charged with the duty of investigating the methods of analysis in use, and of determining the proper methods of such analysis, and that each state should publish an annual report of its proceedings and exchange reports with other states."

NEW FORMS OF ADULTERATION WHICH HAVE APPEARED RECENTLY.—*Arsenic in Food, in Drink, and in Drugs.*—In the preparation of many articles of food and drink, glucose enters as an ingredient, being a cheaper form of sugar than that which is prepared from the sugar-cane. In the manufacture of glucose it is necessary to use sulphuric acid, this acid being removed before the process is completed. The crude sulphuric acid often contains arsenic in consequence of the presence of arsenic in the iron pyrites from which a large part of the acid in the market is made.

Glucose is now used largely in the manufacture of beer, and as a consequence beer-drinkers in England have suffered seriously from arsenical poisoning. From the report of Dr. Buchanan to the local government board, dated February 7th, 1901, it appears that 3,652 cases of arsenical poisoning had occurred in Manchester, Liverpool, Chester, Salford, and neighboring places, and that many deaths had taken place among this number. Most of these persons were habitual beer-drinkers.*

A parliamentary committee was appointed in February, 1901, charged with the duty of investigating this subject and reporting upon it. This committee reported in July, substantially confirming the statement of the local government board. It was found, according to this report, that the glucose used came from one firm of manufacturers of brewing sugar, and upon analysis of several samples by different chemists quantities of arsenic were found, amounting in one instance to 9.17 grains per pound of glucose.

The conclusions of this commission, as summed up in this preliminary report of July 10th, 1901, are as follows:

"On consideration of all the circumstances connected with the recent epidemic, we think that some improvement in administrative measures is called for. It is evident that amendments have to be considered, not only with reference to the question of arsenic in beer, but also in relation to the broader question of the machinery available to public health authorities to obviate the risk of arsenic or other poisonous substances reaching articles of food and drink in general.

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* The standard of whole milk in Paris is a minimum of 11.5 per cent. of solids and 2.7 fat. That of the British Society of Public Analysts is 11.5 total solids and 2.5 fat. That of the State of New York is 12 per cent. of solids and 3 per cent. fat. Of New Jersey 12 per cent. of solids. Of Massachusetts 13 per cent. of solids in winter and 12 per cent. in summer.

* Report to the Local Government Board on "Recent Arsenical Poisoning Attributed to Beer," by Dr. G. S. Buchanan, London, 1901.

"Upon this important general question we consider it essential to await further evidence before making final recommendations. But meanwhile, seeing that the epidemic of 1900 has been caused solely by beer, and that there exists in the case of breweries (although for another purpose) a system of close inspection by a government department—the board of inland revenue—we think that as a provisional measure the machinery under this system might effectively be turned to account to check the introduction of arsenic into beer by way of its ingredients.

"To this end we recommend that the board of inland revenue should possess and should exercise powers to specify in detail individual ingredients of beer which are liable from their origin or mode of preparation to be contaminated by arsenic, to prescribe for every such ingredient, and for the different materials used in their preparation, an adequate test which should insure their freedom from arsenic; and to prohibit, under penalty, the use in a brewery of any material which infringes the prescribed test.

"We are of opinion that by requiring the brewer to produce satisfactory evidence (whether in the form of a guarantee from the vendor, or as the result of analysis by the brewer's chemist, stated in such terms as the board of inland revenue may determine) that the prescribed tests have been applied to all the ingredients of beer at the brewery which have been specified as liable to contain arsenic, and that, by the examination of samples in the government laboratory, an immediate and effective safeguard to the public with regard to arsenic in beer can be secured." *

Among the adulterations which have increased very much in recent years are the various preparations of preserved fruits, jams, jellies, and marmalades, which, in the majority of instances of those which are sold at a low price, are adulterated with a multitude of substances other than those which they profess to be. They are also often highly colored with aniline dyes. Flavoring extracts are also adulterated seriously in many ways, and often contain none of the essential oil which is named upon the label. This form of adulteration has greatly increased in the past two years.

Artificial Coffee Berries.—An artificial coffee berry was made in New Jersey and advertised for sale. The berry was a very good imitation of the genuine in shape and color, but was entirely devoid of the taste of coffee. Its texture was easily distinguished by the microscope, and hence it proved to be a failure as a practicable adulteration. It was composed of burnt flour or starch.

False Nutmegs.—Dr. Vanderplanken† describes an artificial nutmeg having the following characteristics:

1. Absence of vegetable structure on section.
2. When treated for three minutes with boiling water, the nut is softened and breaks into a powder under the pressure of the fingers.
3. The ash amounts to more than eleven per cent., that of the genuine nut being from two to three per cent.
4. They are heavier than the genuine nuts.

A very good photograph of the true and false nuts is presented in the paper of Dr. Vanderplanken.

Coloring Matter.—The use of caramel and annatto is less frequently used for the false coloration of milk, and an aniline dye is now used, the quantity required being comparatively small.

Preservatives.—The use of boric and salicylic acids has increased recently for the preservation of meat, fish, milk, and other perishable articles of food, and still more recently formalin has come into use for the same purpose. The method employed for the detection of formalin is detailed in the report of the State board of health of Massachusetts for 1897.

Saccharin.—The question of the propriety of using saccharin as a sweetening agent in place of sugar is under discussion in France.*

The following list embraces most of the common articles of food which are liable to adulteration, together with the character of the adulteration.

ARTICLES LIABLE TO ADULTERATION, WITH THE CHARACTER OF ADULTERATION.

Name of article.	Harmful adulterants.	Fraudulent adulterations.
Arrowroot		Other and cheaper starches.
Alcoholic liquors.	Excess of fusel oil, harmful coloring matter.	Added water, sugar, alcohol, and coloring matter.
Bread	Alum, used as such; rare in United States.	Other and cheaper kinds of flour than those which are called for. The contained water should not be over forty-five per cent.
Butter		Other animal and vegetable fats, such as beef suet and cotton-seed oil, lard, coloring matter, and excess of water.
Beer	Salicylic acid and other preservatives; arsenic as an impurity in glucose; water polluted with sewage.	Burnt sugar, licorice, molasses, glucose, quassia, salt, etc.
Canned goods	Lead, tin, and zinc from interior of cans and from solder; copper as a coloring agent; harmful preservatives.	Contents of cans damaged by improper sealing and from other causes; use of coloring matter; use of old and damaged articles such as "soaked" peas.
Catsup	Salicylic acid and other preservatives.	
Cheese	Poisonous colors in the rind.	Lard, cotton-seed oil, and deficiency in fats.
Cider	Salicylic acid and other preservatives.	Water.
Cloves		Corn, wheat, allspice, nutshells, peas, ginger, pepper, charcoal, dirt, and clove stems.
Cocoa		Animal fats, starch, flour, sugar, and caramel.
Coffee	Harmful colors	Chicory, dandelion, beans, peas, rye, wheat, almond shells, and brown bread, imitation berries made of burnt starch, etc.
Confectionery	Harmful colors and flavors, terra alba, talc, baryta, fusel oil, and brandy.	The term "confectionery" has no standard and many substances enter into its composition. Glucose is largely used as well as cane-sugar, neither of which is harmful.
Cooking utensils.	Arsenic; antimony and lead in the glazing.	
Dried fruits	Occasional slight traces of zinc from the evaporating trays.	
Flavoring extracts.		Deficiency in essential oils and alcohol; excess of water; substitution of cheaper flavoring ingredients, addition of artificial colors.
Flour		Rarely adulterated in United States except with cornmeal.
Fruit syrups	Aniline colors and flavors.	Coloring agents generally; cheaper fruits and often no fruit whatever.
Ginger		Turmeric, Cayenne pepper, mustard, inferior and exhausted powder.
Gluten meal	Starch (injurious when the meal is employed as a diabetic food). Very few of the so-called gluten meal preparations found in the market consist of true gluten without starch.	
Honey		Glucose, sugar, molasses, syrups, and dead bees introduced for effect.

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* First Report of the Royal Commission appointed to inquire into arsenical poisoning from the consumption of beer, and other articles of food and drink. Part I., London, July 10th, 1901.

† Revue Internationale des Falsifications, vol. xiii., April, 1900, p. 44.

† Revue Internationale des Falsifications, vol. xii., 1899, p. 134.

ARTICLES LIABLE TO ADULTERATION, WITH THE CHARACTER OF ADULTERATION.—*Continued.*

Name of article.	Harmful adulterants.	Fraudulent adulterations.
Horseradish.		Turnips.
Ice cream	Poisonous dyes and flavors and as an accidental ingredient, poisonous ptomains.	
Jams and jellies.	Harmful dyes and flavors.	Glucose, gelatin, substitution of cheaper fruits, cores, parings, and seeds.
Lard		Other animal and vegetable fats and water.
Lime juice	Mineral acids and preservatives.	Tartaric and other organic acids.
Mace		Starches, and substitution of wild mace for true mace.
Maple sugar		Usually cane-sugar.
Maple syrup		Glucose and cheaper cane syrups.
Meat	The product of diseased animals; presence of parasites, and of ptomains.	Substitution of cheaper kinds.
Milk	Substitution of water and removal of cream. These are much more than mere commercial frauds, they rob the milk of its valuable nutritious constituents; use of preservatives.	Addition of coloring matters, caramel, annatto, aniline dyes.
Milk-sugar		Cane-sugar and glucose.
Molasses	Salts of tin	Glucose.
Pickles	Copper, alum, mineral acids.	
Preserves	Aniline dyes and preservatives.	Apples, pumpkins, turnips, glucose, and generally cheaper sorts of fruit, and fruit and vegetable seeds and other refuse products.
Sago		Cheaper starches.
Sausages		Colored with Bismarck brown and other colors. Made from meat of diseased animals.
Spices	Lead coloring matter in Cayenne pepper.	Starches generally, sawdust and other forms of wood, ground nut shells, olive and date stones, turmeric, charcoal, dirt, pepper and mustard hulls, cheaper kinds of spice, removal of essential oils; substitution of wild mace for mace.
Sugar	Salts of tin	Cane-sugar is rarely adulterated in United States except by use of ultramarine, which is employed to give a better color (bluish-white instead of yellowish-white) for same purpose as indigo is added to starch. So far as can be learned the ultramarine is harmless.
Tea	Lead, Prussian blue and other earths.	Leaves of other plants, spent tea, and substitution of cheaper kinds.
Vinegar	Mineral acids and aniline colors.	Glucose, apple pomace and jelly, water; cheaper vinegar for cider vinegar; caramel and other coloring matter.
Wines	Plaster of Paris, sulphur, harmful colors.	Alcohol (fortification), water (dilution), sugar; entire substitution of other articles as cider for champagne; fictitious imitations.

ADULTERATION OF DRUGS.

In nearly all countries in which efficient laws have been enacted for the purpose of preventing the adulteration of food, additional powers have also been provided for similar action in regard to drugs. Since, while it is important that the nutriment intended for the daily support of man should be of the best quality, it is also important that those articles which are used in the treatment of disease should be free from impurity.

In Great Britain and the continental countries of Europe generally, modern legislation for this purpose is very efficient, and the means provided for drug inspection are similar to those which are provided for food, the collections being made by the same set of officials, the examinations by the same analysts, and the work performed in the same laboratories.

ENGLAND.—In England the inspection of drugs is carried out under the provisions of the Sale of Food and Drug Act of 1875. The substance of this act is presented elsewhere in the section on Food Inspection. Dr. Hime says of this statute: "There are probably no statutes of the length of the Sale of Food and Drugs Act which have been the source of as much litigation and of as many appeals."* By the provisions of this act "the term 'drug' includes medicine for external or internal use."

It is also provided that "no person shall treat any drug so as to affect injuriously the quality or potency of the drug, with intent that the same may be sold in that state, under a penalty of not exceeding £50 for the first offence."

Under the operation of this law 235 public analysts have been appointed to carry out the work of inspection of such articles of food and drugs as are collected in the different districts of England.

The following figures present a condensed summary of the inspection of drugs since 1877:[1]

Percentage of adulteration found on examination: For the five-year period 1877–81, 22 per cent.; 1882–86, 13.6 per cent.; 1887–91, 13.1 per cent.; 1892–96, 12.3 per cent.

During the year 1896–97 the percentage of adulteration was 11.3 per cent. During 1897–98 it was 10.5 per cent.

The total number of samples of drugs examined in 1896–97 was 1,380, of which 156 were found to be adulterated. In 1897–98 the adulterated samples were 206 out of 1,964. The principal articles found to be adulterated in 1897–98 were sweet spirits of nitre, 39 samples out of 156; rhubarb, 35 out of 198; quinine, 10 out of 99; sulphur, 2 out of 90; glycerin, 23 out of 345; lime water, 13 out of 20. To these should be added in the former year: wine of ipecac, 10 samples out of 29; and beeswax, 10 samples out of 46.

The number of prosecutions conducted in 1897–98 against offenders of this class was 87, and 53 fines were imposed.

GERMANY.—The German code of laws relating to the sale of drugs is contained in a series of statutes which have been enacted and amended at different times during the past century. Special care is given in these statutes in relation to the sale of poisons, and lists of such poisons are published, allowing certain classes of poisons to be sold under restrictions (Law of 1890, January 27th).[2]

The law in regard to the sale of proprietary medicines is also quite explicit. By these statutes it is provided:

1. That unapproved panaceas cannot be sold.

2. In consequence of the unrestricted sale of patent medicines of a worthless character, a decree was published in 1867 that "all requests for the right to prepare and sell a secret remedy, although shown to be harmless, will be denied to private individuals, but concessions granted exceptionally in former years are to expire with the decease of the persons to whom they are granted, and cannot be transmitted to others."

3. Advertisements or private announcements of secret remedies are strictly forbidden.

In Berlin the police authorities cause patent medicines to be analyzed with reference to their composition. Attention is also paid to the price of such articles, and if necessary they can acquire information relative to the methods of manufacture. It is also allowable to publish the composition, the actual value as a remedy, and also any facts that may be revealed as to the character of the manufacture, and if necessary to warn the public against its use.

These regulations have had a salutary influence in Berlin, and have had the effect of driving the traffic in such articles into outlying provinces, where the manufacturers continue to plunder the public without hindrance (und daselbst das Publikum auszubeuten versuchen) (Ministerial Rescript of April 10th, 1886).

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*"The Practical Guide to the Public Health Acts," by Thomas Whiteside Hime, B.A., M.D., London, 1901.

United States.—A statute existed in several States at an early date, providing that "whoever adulterates, for the purpose of sale, any drug or medicine, or sells any fraudulently adulterated medicine, knowing the same to be adulterated," shall be subject to a penalty.[*] Experience has shown, however, that laws of this character, requiring proof of guilty knowledge of the fact of adulteration in order to secure conviction, are of but little value in affording protection to the community. Hence it was that in subsequent legislation the *sale* of adulterated articles was deemed to be an offence subject to a penalty. Under the rigid enforcement, however, of such a law, much hardship might be inflicted upon retailers who purchase most of their stock at wholesale, and systems have therefore been devised by which retailers have been given the benefit of a warning notice to the effect that certain articles sold by them were adulterated, and that their sale should not be continued, or that they should be sold under some legal limitation, with the understanding on the part of the purchaser that they were goods of inferior quality. Such notices are usually forwarded direct to the wholesaler, and have a wholesome effect in correcting abuses.[3]

In a report made by C. L. Diehl to the national board of health in 1880[4] appears the following statement: "Previous to 1848 and for some years afterward, the condition of the drug market appears to have been in a very unsatisfactory state. This condition was largely attributed to the importation of inferior and adulterated drugs, which, in the absence of a law specifying a standard of quality, were freely admitted at our ports of entry. In 1848 Congress passed a law regulating the importation of drugs, which went into effect July 15th of that year, and during the first ten months Dr. M. I. Bailey, the special examiner at New York, had occasion to reject about 90,000 lbs. of drugs, such as rhubarb, senna, opium, jalap, gamboge, iodine, croton oil, sarsaparilla, etc.; and during the administration of his office, from 1848 to 1857, he found it necessary to reject over 900,000 lbs. of 'unsafe,' adulterated, and improper drugs and medicines. As a result of this action, the character of the drugs imported soon showed decided improvement."

The operation of this law does not appear to have been entirely satisfactory, if we may judge from the report of a committee of the American Pharmaceutical Association, which in 1855 "referred to the disregard that is paid to proper qualifications in the appointment of officers to carry out the requirements of the drug law." At a later date Mr. Diehl says: "Some attention is paid to the fitness and qualification of applicants, and the execution of the law is in the main satisfactory, though by no means incapable of being improved and rendered more efficient by wise revision."

After the establishment of State boards of health, investigations were begun in several States relative to the quality of the drugs found and offered for sale in these States, the result showing that legislation was necessary to prevent adulteration in the sale of drugs as well as in their importation. Laws have therefore been enacted, usually in conjunction with the food laws, for protection against this class of adulterations.

The term "drugs" in the Massachusetts Act of 1882 embraces "all medicines for internal and external use, antiseptics, disinfectants, and cosmetics." Hence the work of the State board of health, in this direction, has not been confined to the remedies defined in the United States Pharmacopœia, but has embraced many other articles, and especially empirical preparations of a more or less harmful character.[5]

The following section of the Massachusetts Act presents the requirements of the law relating to the standard of pure drugs, and has been enacted in practically the same form in the following States, according to Dr. Chapin:[6] California, Connecticut, District of Columbia, Illinois, Indiana, Kansas, Kentucky, Michigan, Mississippi, Nebraska, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, South Dakota, Tennessee, and Wisconsin.

Acts of 1882, 263, § 3, Mass., as amended by later statutes.

An article shall be deemed to be adulterated within the meaning of this act—

(*a*) In the case of drugs: (1) If, when sold under or by a name recognized by the United States Pharmacopœia, it differs from the standard of strength, quality, or purity laid down therein, unless the order calls for an article inferior to such standard, or unless such difference is made known or so appears to the purchaser at the time of such sale; (2) if, when sold under or by a name not recognized in the United States Pharmacopœia but which is found in some other pharmacopœia or other standard work on *materia medica*, it differs materially from the standard of strength, quality, or purity laid down in such work; (3) if its strength or purity falls below the professed standard under which it is sold.

Of the drugs found to be of a specially inferior quality during the earlier investigations of the analysts in 1883 and 1884 were the following:

Tincture of opium (U. S. P., 1.20 to 1.60 parts per 100 of morphine), 144 samples out of 197 fell below the required limit of 1.2, and some had as little as 0.01, 0.14, 0.17, or a mere fraction only of the minimum requirement. Citrate of iron and quinine (legal requirement twelve per cent. of quinine), eighty-five per cent. of the samples had less than the required amount, and several had as little as 3 and 3.5 per cent., or but little more than a quarter of the requirement. Of powdered jalap only one sample out of twelve conformed to the pharmacopœial standard. Of 192 samples of powdered drugs, 39 were found to be adulterated in various forms. Of 19 samples of compound spirits of ether, 2 only contained the required amount of the ethereal oil required by the statutes. Of 23 samples of spirit of nitrous ether, scarcely any had the required amount of ethyl nitrite.

Twenty-two samples or lots of the quinine pills made by different manufacturers were examined. These were examined in two groups, at an interval of several months, during which time the manufacturers had become aware of the work of the board in this direction. The analysis of the second group showed in nearly every instance an improvement. The following figures indicate the percentages of the required weight of the pills made by nine manufacturers, in the two series of analyses:

	First series.	Second series.
1.........	93.5	97.9
2.........	86.6	97.3
3.........	93.3	99.6
4.........	93.8	100.7
5.........	107.6	76.5
6.........	84.7	89.5
7.........	93.8	101.1
8.........	104.4	100.5
9.........	97.0	97.1

The foregoing list shows an improvement in each case except two. Of 106 samples of pharmacopœial spirits and wines, only 10, or 9.4 per cent., conformed to the legal requirements.

In proof of the improvement under the action of the statutes, very marked changes for the better have been found to have taken place in many of the foregoing articles.

Among the non-pharmacopœial preparations examined in 1885 were 11 hair dyes, all of which contained lead in large amounts; also 20 different fraudulent nostrums advertised for the cure of the opium habit, most of which were solutions of morphine. One of them was the so-called "Keeley gold cure," which was found to contain no gold whatever. In 1887 about fifty proprietary articles, sold as tonics and bitters (some of which were advocated as temperance drinks), were examined chiefly for their alcoholic contents. All were found to contain alcohol in the proportion of six to forty-eight per cent. by volume. One of these, which was advertised as a remedy for inebriety and the opium habit, was the celebrated "Scotch oats essence," containing alcohol and morphine, the latter in varying proportions. This nostrum very soon disappeared after its analysis had been published. Cocaine as a common ingredient in the composition of remedies for asthma, hay fever, and catarrh has also been the subject of examination.

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[*] Law of 1853, Mass., P. S. 208, § 5.

Cosmetics for the complexion, termed face bleaches, freckle lotions, skin tonics, have been examined and found to consist of strong solutions of corrosive sublimate. Of this class were Ruppert's complexion bleach, and Yale's complexion bleach, Perry's freckle lotion (39 grains corrosive sublimate in an eight-ounce bottle), and Mrs. McCorrison's diamond lotion.

Skin Success Ointment contained red oxide of mercury. Cocaine as an active ingredient was found in Dr. Birney's catarrh remedy, Instant cold relief, Dr. Tucker's asthma cure, Azmasyde, and Coca-kola.

It was required that such articles, if sold at all, should be labelled as poisons, and sold only under careful restrictions. Seventeen complaints were made against parties selling the most poisonous of these articles in violation of the statutes.

The powerful influence of the proprietary medicine interest, however, prevailed, and that section of the statutes which required that poisonous patent medicines should be labelled as poisons was repealed, so that the people are now deprived of that protection which was once afforded by law.

As an evidence of the character of the most poisonous of these preparations (cosmetics), it may be said that the cost of a bottle of face bleach which sells at $2 is about five cents, bottle included, and the package is often marked "harmless."

In later years the following were some of the more important adulterations found upon analysis:

In 1897, of 18 samples of chlorinated lime, all proved to be below the required standard. Eight of these were very deficient in available chlorine. All the samples obtained in 1898 and 1899 were also deficient.

Of distilled water, only 19 samples out of 69 obtained in 1897, 1898, and 1899 were free from solid residue. The highest amount of solid residue in any sample was 23.7 per 100,000. A comparison of the water collected from drug stores in certain localities with that collected from the public water supplies of the same cities and towns, made it apparent that it was quite a common custom for druggists to fill orders for distilled water from the faucet supplying the city water.

Of 61 samples of powdered opium collected in the same years and in 1900, 20 were deficient in morphine strength. (This result shows a decided improvement over the samples collected in 1883-84.) Of 172 samples of tincture of opium, 133 were deficient, but many of them were quite near the minimum limit of 1.3 per cent. of morphine.

Of 30 samples of compound spirits of ether, 18 were deficient in ethereal oil.

Of 113 samples of tincture of iodine, 95 were deficient in iodine.

Of 156 samples of olive oil, 47 were either wholly or in part cotton-seed oil.

Of 37 samples of lime juice, all except 1 contained salicylic acid; and one sample marked "Santiago, W. I., triple refined," consisted of a dilute solution of hydrochloric acid flavored with oil of lemon and preserved with salicylic acid. It contained no lime juice whatever.

Thirteen samples of so-called diabetic flour were examined for starch, and only 3 were free from it; 7 of these contained as much as 60 per cent. of starch in each sample.

In 1900 and in 1901 special attention has been given to the analysis of drugs for arsenic, with the result of finding it in appreciable amounts in glycerin and in phosphate of soda.

Of 11 samples of grape juice collected in 1900 5 were found to contain either boracic or salicylic acid.

The pharmacopœial wines and liquors were found to be quite generally falsified by the addition either of alcohol, water, or sugar, and only very rarely with substances of a more injurious character than the alcohol.

New York.—The State board of health of New York for several years maintained a system of drug inspection under the direction of a competent chemist, which was practically discontinued in 1895 by withdrawal of the necessary appropriation.[7]

In its report for the year 1893, it appears that 2,637 samples of drugs were collected and 2,434 were examined, making a total of 7,035 samples collected and 6,832 examined since 1891. These were all officinal articles having a definite standard, and of these 1,018, or 41.9 per cent., were of "good" quality; 446, or 18.4 per cent., were classed as "fair"; 699, or 28.7 per cent., as "injurious"; 131, or 5.3 per cent., were "not as called for"; and 140, or 5.7 per cent., were of "excessive strength."

The principal articles were as follows:

Dilute acetic acid, 231 samples examined, 61 good, 52 fair, 78 inferior, 34 excessive strength, 6 not as called for.

Water of Ammonia, 297 samples, 77 good, 66 fair, 94 inferior, 54 excessive strength, 6 not as called for.

Capsicum, 17 samples, 13 good, 1 fair, 3 inferior.

Creosote, 222 samples, 119 good, the remainder consisted chiefly of carbolic acid.

Compound Spirits of Ether, 206 samples, 54 good, 22 fair, 129 inferior.

Stronger Ether, 144 samples, 91 good, 7 fair, 46 inferior.

Ginger, 15 samples, all good.

Dilute Hydrochloric Acid, 232 samples, 151 good, 45 fair, 32 inferior, 4 excessive strength.

Compound Solution of Iodine, 100 samples, 68 good, 23 fair, 7 inferior, 1 excessive strength, 10 not as called for.

Tincture of Iodine, 237 samples, 57 good, 96 fair, 81 inferior, 3 excessive strength.

Ipecac, 15 samples, all good except one.

Tincture of Iron, 21 samples, 19 good, 2 fair.

Magnesia, 111 samples, 52 good, 3 fair, 50 inferior, 6 not as called for.

Aromatic Sulphuric Acid, 289 samples examined, 29 good, 93 fair, 167 inferior.

Dilute Sulphuric Acid, 259 samples, 171 good, 33 fair, 11 inferior, 44 excessive strength. *Samuel W. Abbott.*

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FOOD: METHODS OF INSPECTION AND ANALYSIS.

FOOD: METHODS OF INSPECTION AND ANALYSIS.—There is no field of chemical analysis more unique in itself than that covered by the food analyst, who necessarily employs methods of a much more varied character than almost any other chemical specialist. Processes of food analysis are not exclusively chemical. Physical methods are frequently employed, especially those along optical lines involving the use of the microscope, the polariscope, the spectroscope, and the refractometer. Besides these instruments, the food analyst should be provided with a water bath, a delicate balance, a Babcock centrifuge, the usual laboratory glassware and reagents, and, if possible, with a number of platinum dishes.

It is desirable in the examination of foods to employ quick processes for separating the pure from the impure, afterward applying special methods to the impure samples to ascertain the nature and extent of the adulteration.

No attempt is made in what follows to deal with the processes of analyzing foods for their nutritive values, but simply briefly to outline methods of detecting, and in some instances estimating adulterants in such classes of food products as experience has shown to be most liable to fraudulent adulteration. Wherever possible, methods are selected involving the simplest possible apparatus. The usual laboratory reagents are used, mainly solutions of simple salts, and for their preparation the reader is referred to any text book in qualitative analysis.

Baking Powder.—The adulterants of cream of tartar are, of course, to be looked for in baking powder, and are tested for as indicated under "Cream of Tartar."

Alum is tested for by burning a small quantity of the sample to an ash, which is then treated with boiling water and filtered. If, on the addition of ammonium chloride to the filtrate, a flocculent precipitate is formed, this will indicate the presence of alum in the sample. The test is applicable in presence of phosphates.

Butter.—If accustomed to the odor and taste of oleomargarine, one can usually distinguish by these senses alone between it and pure butter. The odor of the melted fat is very distinctive, the melted oleomargarine lacking the butyric odor so characteristic of the butter and possessing a distinct "meaty" smell that generally betrays its nature. Certain quick physical tests are sometimes employed to distinguish pure from adulterated butter.

The Spoon Test.—If about a gram of the sample be placed on a spoon, held over the free gas flame and brought to the boiling point, the mass will assume a "foamy" appearance if the butter is pure. If the sample is oleomargarine or "process butter" (old butter reworked), the mass will bump and spatter like hot grease containing water, but does not foam.

The Milk Test.—Five to 10 c.c. of the sample are added to 50 c.c. of sweet milk heated nearly to boiling. The contents are stirred with a rod till the fat is melted, after which the container is placed in cold water and the stirring is continued till the fat congeals. If oleomargarine, the fat can readily be collected into one lump with the stirring rod, and if butter, it cannot be gathered together, but granulates.

Under the microscope pure butter should theoretically show no crystalline structure when viewed by polarized light, being uniformly bright throughout and, if the selenite plate be used, showing an evenly colored field entirely devoid of fat crystals. With process butter or oleomargarine, both of which have been melted and subsequently cooled, the crystalline structure should be marked, showing with polarized light a mottled appearance, and a play of colors with the selenite. These conditions are, however, not sufficiently sharp to be reliable in unskilled hands.

The Zeiss Butyro-Refractometer furnishes a ready means of distinguishing between butter and oleomargarine. This instrument is so constructed that the degree of refraction of a beam of light reflected from a mirror obliquely through a thin film of the melted fat is read on an arbitrary scale of sufficient extent to cover the widest limits of deviation possible for butter fat and oleomargarine under ordinary temperatures. The butter fat is kept at a constant temperature above the melting point by a circulation of heated water maintained through a jacket that encloses it, the temperature being read on a thermometer. Each fat has fixed limits of reading at a given temperature, the scale reading of oleomargarine being from six to twelve degrees higher than that of butter.

The Volatile Fat Acids.—The presence of a considerable percentage of volatile fatty acids in genuine butter and the lack of them in oleomargarine furnishes the most ready chemical means of distinguishing between the two. The result is usually expressed by the number of cubic centimetres of decinormal alkali necessary to neutralize the volatile fatty acids in 5 gm. of the fat, being known as the "Reichert number." The method of obtaining this is fully described in Bulletin 46, United States Department of Agriculture, Division of Chemistry.

Cheese.—*The Fat Content* of cheese is the most important factor in determining whether whole or skimmed milk has been used in its manufacture, and the Babcock milk tester is used with advantage in estimating the fat.

Weigh 5 gm. of the finely divided sample into a tared Babcock milk testing bottle. About 15 c.c. of hot water are then added, and the mixture is shaken until an emulsion is formed. A few drops of ammonia aids in softening the cheese. The mixture is kept warm by immersing the test bottle in hot water. When a complete emulsion is formed, the bottle is cooled, 17.5 c.c. of concentrated sulphuric acid are added and the test is completed in the usual manner for carrying out the Babcock test (see Milk Fat). The reading of the fat in the bottle is multiplied by 18 and this result divided by the number of grams of the sample taken gives the percentage of fat in the cheese, which in case of a whole-milk cheese should be at least thirty per cent.

Detection of Foreign Fat.—The presence of foreign fat in cheese is best detected by submitting the separated cheese fat to the same examination as is given to butter fat (*q. v.*), the fat for chemical examination being best removed by extraction of the cheese with ether.

Cocoa.—The purity of cocoa is best determined by means of the microscope. See "Spices" for brief directions as to mounting, etc. Samples of known purity should be studied for comparison with doubtful specimens. Under the microscope pure cocoa shows a loose mass of yellowish-brown matter, with small starch granules and oil globules.

Coffee.—This, like cocoa, is best examined microscopically, being first ground to a fine powder in a mortar. Figs. 6, 7, 8, Plate XXVI., show the characteristic appearance under the microscope of both pure and adulterated samples. Pure coffee appears as a mesh-work of irregular hexagonal thick-walled cells enclosing oil droplets and amorphous material.

Condensed Milk.—Forty grams of the thoroughly mixed sample are weighed out and made up to 100 c.c. with water.

Total Solids.—An aliquot part of the above solution is further diluted with an equal amount of water, and 5 c.c. of the diluted mixture is evaporated over the live steam of a boiling water bath for three hours in a platinum dish and the residue weighed.

Ash.—The residue from the total solids is burnt to a white ash and weighed.

Fat.—This is the most important factor in determining

EXPLANATION OF
PLATE XXVI.

EXPLANATION OF PLATE XXVI.

Fig. 1.—Pure Cayenne. Patches of the inner and outer skin appear most prominent, with scattered bits of cellular tissue.

Fig. 2.—Cayenne Adulterated with Wheat. The mass to the left of the centre is cayenne. The circular granules are of wheat starch.

Fig. 3.—Allspice Adulterated with Cayenne. The large mass is cayenne skin. The small stone cell and mass of gum below are of allspice.

Fig. 4.—Pepper Adulterated with Buckwheat. Large masses of buckwheat starch granules are above the centre, and a small mass of finer pepper-starch grains below and to the left.

Fig. 5.—Olive Stones in Alleged Pepper. Elongated, thick-walled stone cells of the ground fruit stones are grouped together in the centre.

Fig. 6.—Pure Coffee. A meshwork of cells tending to hexagonal in shape, enclosing amorphous material and droplets of oil.

Fig. 7.—Coffee Adulterated with Peas and Pea Hulls. Masses of pea-starch granules are most prominent. The rectangular billets, like bunches of matches around the lower edge, constitute the pea hulls.

Fig. 8.—Chicory in an Adulterated Coffee. Chicory shows as a mass of cellular tissue, traversed by broad bands (juice ducts) having striking transverse markings.

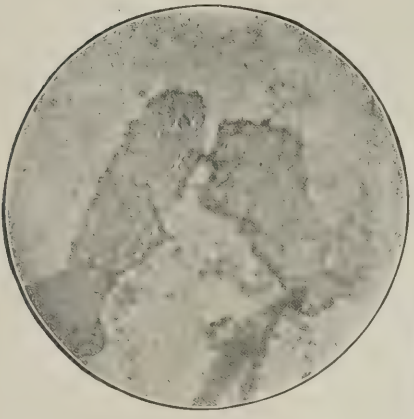

FIG. 1.—Pure Cayenne.
× 110.

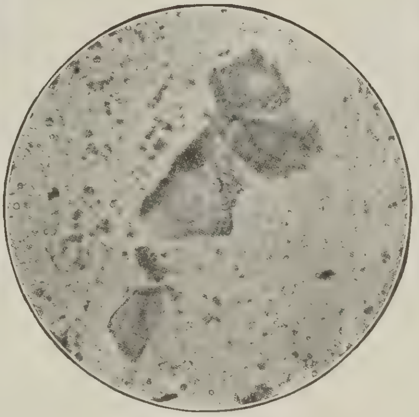

FIG. 4.—Pepper Adulterated with Buckwheat.
× 130.

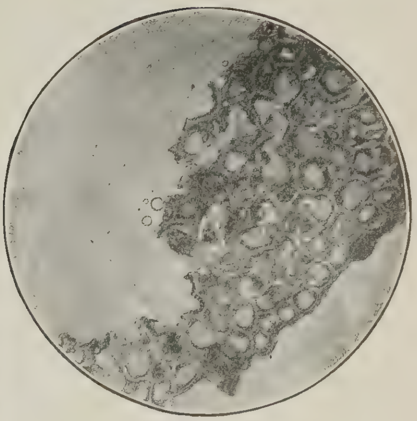

FIG. 6.—Pure Coffee.
× 130.

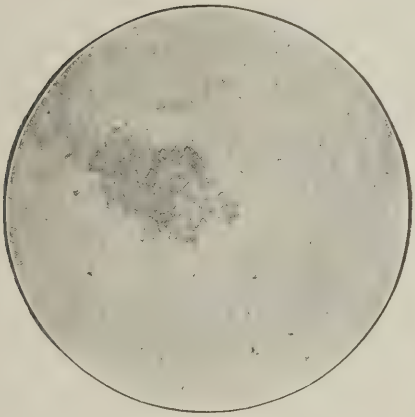

FIG. 2.—Cayenne Adulterated with Wheat.
× 130.

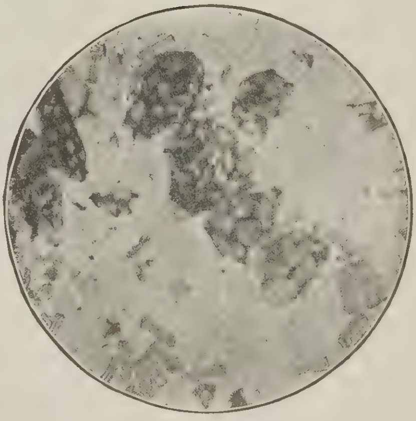

FIG. 7.—Coffee Adulterated with Peas and
Pea Hulls.
× 130.

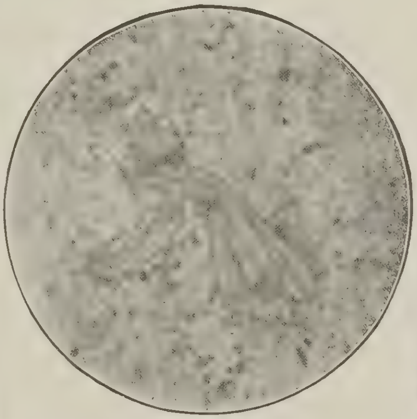

FIG. 5.—Olive Stones in Alleged Pepper.
× 110.

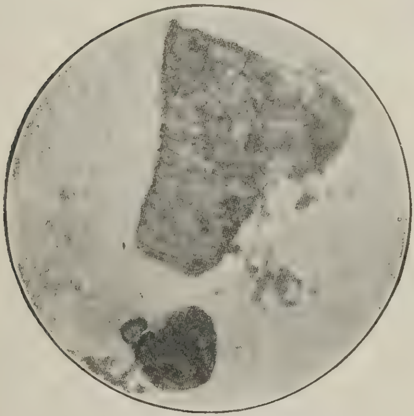

FIG. 3.—Allspice Adulterated with Cayenne.
× 110.

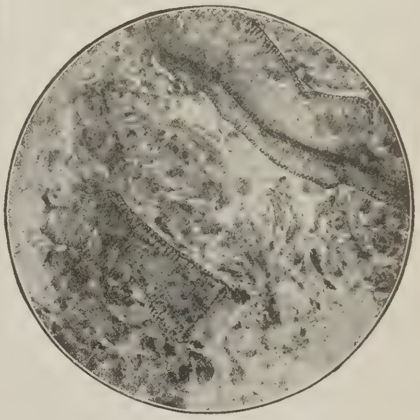

FIG. 8.—Chicory in an Adulterated Coffee.
× 130.

PHOTOMICROGRAPHS OF PURE AND TYPICALLY ADULTERATED
FOODS AND ADULTERANTS

OF THE
UNIVERSITY of ILLINOIS

the purity of the sample. Twenty-five cubic centimetres of the forty-per-cent. solution are measured into an ordinary Babcock test bottle, which is then filled nearly to the neck with water. The contents are shaken and 4 c.c. of a seven-per-cent. solution of copper sulphate are added. The bottle is then well shaken and whirled in the centrifuge until the precipitate has settled out. The clear supernatant liquid is drawn off by means of a pipette, a small wisp of absorbent cotton being lightly twisted about the lower end to serve as a filter. After the liquid is drawn up into the pipette, the cotton is removed by rubbing against the inside of the bottle, and the pipette is withdrawn. The precipitate is washed twice as above by decantation, and after the final washing, sufficient water is added to amount to about the quantity of milk measured for the Babcock test (17.6 c.c.). From this point on the usual Babcock centrifuge method is followed, adding the regular 17.5 c.c. of strong sulphuric acid (see Milk Fat). Multiplying the final reading by 1.8, we get the percentage of fat.

The above process is to be used for the ordinary condensed milk containing added cane-sugar. The fat in "evaporated cream," which is really condensed milk without the cane-sugar, is best determined by the ordinary Babcock method as in the case of milk, using 17.6 c.c. of a uniform mixture of equal volumes of the sample, and water.

CREAM is treated similarly to milk (*q. v.*) for total solids, color, and preservatives.

Fat.—A weighed portion of the sample is introduced into the specially constructed cream bottle furnished for the Babcock test. The test is then conducted as in the case of milk fat (*q. v.*), the final reading being multiplied by 18 and the result divided by the number of grams of the sample taken to give the exact percentage of fat.

Gelatin, sometimes used to thicken cream, is best detected by mixing 10 c.c. of the cream with an equal volume of a dilute solution of acid nitrate of mercury. After diluting and shaking, the mixture is allowed to stand a few minutes and filtered. To a portion of the filtrate an equal quantity of a saturated solution of picric acid is added. A yellow precipitate indicates gelatin.

CREAM OF TARTAR.—The purity of this substance is usually established if the sample is found to be readily soluble in hot water; since most adulterants other than alum are insoluble. It is best to weigh out 0.1881 gm. of the cream of tartar and dissolve in hot water, titrating the solution with one-tenth normal sodium hydroxide, and using phenolphthalein as an indicator. If the sample is pure, it should require just 10 c.c. of the alkali to neutralize.

If *alum* is the adulterant, the alum would be precipitated by the sodium hydroxide, the precipitate being soluble in an excess of the alkali.

Starch is detected by adding a drop of iodine reagent to the solution of the sample, a blue color being produced if starch is present. The starches are most readily identified under the microscope.

Calcium (present as sulphate or phosphate) is best shown by burning the sample to an ash, dissolving in water acidified with hydrochloric acid, filtering, and treating a part of the filtrate with ammonia and ammonium oxalate. A precipitate shows calcium.

A Sulphate is indicated, if, on treatment of a part of the acid filtrate above obtained with barium chloride reagent, a precipitate is formed.

A Phosphate is detected by boiling a little of the sample with nitric acid and adding ammonium molybdate reagent. A yellow precipitate indicates phosphate.

HONEY.—*Commercial Glucose* and *Cane-Sugar* are best estimated by means of a Schmidt and Haensch polariscope. 26.048 gm. of the sample are weighed out in a flask graduated to hold 100 c.c., 5 c.c. of alumina cream* are added to clarify, and the solution is made up to 100 c.c. with water. It is well shaken and filtered, the filtrate being polarized in a 200 mm. tube and the reading taken. If the scale reading is to the left of the zero point, the honey may usually be considered pure; if it is to the right, the honey is probably adulterated with cane-sugar or commercial glucose or both. Fifty cubic centimetres of the filtrate are taken, 5 c.c. of strong hydrochloric acid are added, after which the solution is made up to 100 c.c. with water and heated in the flask to 68° C., cooled and filtered. This process is termed inversion. The filtrate is then polarized in the 200 mm. tube, and the result multiplied by two gives the invert reading. The amount of cane-sugar is obtained by the following formula (Clerget's):

$$R = \frac{100\ S}{144 - \frac{1}{2}t}$$

wherein R is the per cent. of cane-sugar, S the difference of the two polarizations before and after inversion, and *t* the temperature at which the readings are taken. If commercial glucose is suspected, the portion of the sample subjected to inversion is heated and polarized at 87° C. in a 200 mm. jacketed tube, the reading being multiplied by two. This result, divided by 175, gives the approximate per cent. of commercial glucose in the sample.

The presence of commercial glucose may usually be qualitatively detected by submitting the sample to a test for dextrin, one of the chief ingredients of glucose. A solution of the honey is treated with an excess of strong alcohol. A precipitate indicates dextrin. Pure honey should give no precipitate.

LARD.—The color, smell, and consistency of the sample of adulterated lard often serve to betray its character to a careful observer, and, as in the case of butter, the odor of the fat when melted is much more distinctive than when in its natural condition. The adulterants commonly to be looked for are cotton-seed oil and beef tallow.

Reaction with Strong Acid (sulphuric or nitric).—A small amount of melted fat is poured into a test tube, an equal quantity of acid is added and the contents are well shaken. Genuine lard and beef stearin usually give but slight coloration, while mixtures containing cotton-seed oil invariably give a red-brown color, more or less intense in proportion to the amount of cotton-seed oil present.

The Zeiss Refractometer, described under "Butter," is useful in the examination of lard as well as other fats and oils. The refracting degree of cotton-seed oil on this instrument is about 8.9 in excess of that of lard, while that of beef tallow is about 3.8 less. If the scale reading of the sample is unusually low, the presence of beef stearin is to be suspected; if unusually high, cotton-seed oil should be looked for. A mixture of the two adulterants either with or without pure lard may be such as to give refractometric readings within the limits of pure lard. In such a case the positive detection of the cotton-seed oil by the Halphen test (given below) will indirectly show the presence of the tallow, which should be confirmed by crystallization and microscopic examination.

Halphen's Test for Cotton-Seed Oil.—A mixture is made of equal volumes of amyl alcohol and carbon bisulphide containing one per cent. of sulphur. From 3 to 5 c.c. of melted fat is mixed with an equal volume of the above reagent in a test tube and heated in a bath of boiling water for fifteen minutes. If cotton-seed oil is present, a deep red or orange color is produced. If the lard is pure, little or no color is developed.

Microscopical Examination of the Crystallized Fat.—From 2 to 5 gm. of the fat are dissolved in 10 to 20 c.c. of a mixture of equal parts of ether and alcohol in a test tube, and the solution is allowed to stand a few hours, the tube being loosely stoppered with cotton. The crystals obtained vary somewhat with the condition of heat, rate of crystallization, etc. A careful study of these crystals and comparison with samples of known purity, crystallized under similar conditions, should be made.

Theoretically, pure lard crystallizes under the best conditions in thin, flat, rhomboidal plates, while beef-stearin crystals are more in the form of cylindrical rods or needles, often bent or curved. Both forms are often found in fan-shaped clusters, which, however, differ from each other in certain important particulars, best distinguished by a careful study of their appearance.

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* Prepared by adding ammonia water in excess to a saturated solution of alum and washing free from ammonia. The aluminum hydrate held in water is shaken so as to form a thin, emulsion-like paste to clarify.

MAPLE SUGAR AND SYRUP.—Commercial glucose is determined in maple syrup precisely as in the case of molasses (*q. v.*) excepting that as a rule no clarifier need be used for maple syrup. A normal solution of pure maple syrup should polarize at from 60° to 64° on the cane-sugar scale. Cane-sugar other than maple is best detected both in syrup and sugar by the sense of taste.

MILK.—There are various simple appliances for roughly testing the quality of milk, but most of them are of little value. The lactometer test is perhaps the best of these, if used with judgment.

The Lactometer is simply a hydrometer covering the widest variations in specific gravity of milk. A thermometer is also necessary and for this reason a Quevenne lactometer, combining in one instrument both the hydrometer and thermometer is convenient. Milk of good quality should have a specific gravity between the limits of 1.027 and 1.033. A watered milk would run below the former, and a skimmed milk above the latter figure, though a milk unusually rich in fat would also run low. It should easily be apparent from the taste and appearance of the milk whether a low specific gravity is due to watering or to unusual richness in cream.

Feser's Lactoscope gives an approximation of the amount of fat in the milk, and its use, especially in connection with the lactometer, is of some value. This instrument consists of a glass cylinder with graduations indicating the per cent. of fat. A measured amount of milk being introduced by means of a pipette, sufficient water is added with thorough mixing to allow certain black lines on a spindle within the cylinder to become apparent through the translucent fluid. The height of the level of milk and water in the cylinder is then read off, indicating roughly the per cent. of fat in the milk.

Total Solids.—Five grams of the thoroughly mixed milk are weighed from a pipette into a tared shallow platinum dish on the pan of a delicate balance, and the dish is transferred to a boiling water bath, where it is kept for at least two hours in direct contact with the live steam. It is afterward cooled and weighed, the residue being the total solids and the loss in weight being reckoned as water.

Ash.—The residue from the total solids is burnt to a white ash and weighed.

Fat.—The fat is most readily determined by the Babcock process. There are various forms of Babcock centrifuge from the simple hand machine to the steam or electrically driven variety, all carrying the same form of graduated bottle. Into this bottle 17.6 c.c. of the thoroughly mixed milk to be examined is introduced by a pipette, the same amount of concentrated sulphuric acid is added and well mixed with the milk to dissolve the albuminoids and set free the fat, after which, by whirling and by the addition of hot water, the fat is driven into the graduated neck of the bottle, where the exact percentage is directly read off.

Calculation of the Total Solids.—The total solids may readily be calculated with considerable approach to accuracy, if the specific gravity and the fat are known, from the formula of Babcock:

$$\text{Total solids} = 0.25\,G + 1.2\,F.$$

G being the lactometer reading and F the fat. This method of obtaining the total solids by calculation is convenient, when, as is often the case, dairymen and others are provided with the inexpensive and easily operated Babcock apparatus and lactometer, but do not have the more involved and costly appliances necessary for the direct determination of the solids.

Distinguishing Watered from Skimmed Milk.—The proportion of solids not fat to fat determines whether a sample below the standard is skimmed or watered. If both these factors are abnormally low, and the proportion of fat to solids not fat is about the same as, or higher than in a normal milk, the sample may as a rule be assumed to be watered; if both total solids and fat are considerably below the standard, and the solids not fat nearly normal, the milk has undoubtedly been skimmed; if total solids and solids not fat are proportionally low, while the ratio of fat to solids not fat is abnormally small, the milk has probably been both skimmed and watered. From legal standards fixed in various States the total solids in pure milk should run from 11.5 to 13.0 per cent., the fat from 3 to 4 per cent., and the solids not fat from 8.5 to 9.3 per cent.

Foreign Coloring Matter.—This may be determined as follows: about a gill of the milk is curdled by heat and acetic acid, the curd being separated and gathered by a stirring rod into one mass. It is then squeezed free from whey and shaken with ether in a corked flask, where it is allowed to macerate for an hour or more. The ether extract containing the fat and annatto, if present, is evaporated and the residue made alkaline with sodium hydroxide and filtered through a wet filter. If annatto is present, it will permeate the filter paper, coloring it a more or less deep orange more apparent when the fat is washed off and the filter is dried. Stannous chloride solution will turn the orange stain pink, if the color is annatto. After pouring off the ether, if the curd is left white, neither caramel nor aniline orange is present. If the aniline dye has been used, the curd will show a more or less brilliant orange color; if caramel, the curd will be brown.

Shake a small portion of the fat-free curd in a test tube with strong hydrochloric acid. The caramel-colored curd will, like an uncolored curd, gradually produce a deep blue color in the strong acid solution. The aniline orange if present in the curd will *immediately* produce with the hydrochloric acid a deep pink color.

Preservatives.—(*a*) *Formaldehyde* is best tested for by heating about 10 c.c. of the milk with an equal quantity of concentrated hydrochloric acid and a drop of ferric chloride solution. A violet coloration is produced if formaldehyde be present, delicate to 1 part formaldehyde in 300,000.

(*b*) *Boracic Acid* is tested for by soaking turmeric paper in a solution of the milk ash, acidified slightly with hydrochloric acid. On drying the turmeric paper, a cherry red color indicates the presence of boracic acid, which is confirmed by applying to the reddened paper a drop of a dilute solution of sodium hydroxide. This reagent turns the paper a dark olive if boracic acid was present.

(*c*) *Carbonate of Soda* is indicated by an effervescence on treating the milk ash with acid, and may further be tested for by mixing 10 c.c. of milk with an equal volume of alcohol and a few drops of a one-per-cent. solution of rosolic acid. A rose red coloration indicates carbonate.

MOLASSES.—*Determination of Commercial Glucose.* Direct and invert polariscopic readings are obtained as directed under "Honey," except that instead of clarifying with alumina cream as in the case of honey, from 5 to 25 c.c. of United States Pharmacopœia subacetate of lead solution are used, depending on the color of the sample, the darker the molasses the more clarifier being necessary. The polarizations should be made in a 100 mm. tube, if the sample is high in glucose, and the proper correction made. If molasses is of average color, its normal solution should polarize less than 60° in the 200 mm. tube on the cane-sugar scale. A dark sample should, if pure, polarize under 50°. Determine the cane-sugar by Clerget's formula (see *Honey*). The cane-sugar deducted from the direct polariscopic reading gives the reading due to glucose. This result, divided by 175, gives the per cent. of commercial glucose.

OLIVE OIL.—As in the case of lard, the presence of cotton-seed oil, which is the most common adulterant, may often be roughly shown by the reaction with strong nitric acid. When shaken in a test tube with an equal volume of the acid, pure olive oil should show a green coloration, while if cotton-seed oil is present, a red color is quickly developed.

The Zeiss Refractometer, though primarily intended for

EXPLANATION OF
PLATE XXVII.

EXPLANATION OF PLATE XXVII.

Fig. 9.—Pure Cloves. A large mass of the loose spongy cellular tissue is shown, filled with brown, granular material.

Fig. 10.—Cloves Adulterated with Cocoanut Shells. Little show in the field but the long dark-colored stone cells of the adulterant.

Fig. 11.—Corn Starch. Hexagonal granules with rifted central hila.

Fig. 12.—Ginger Adulterated with Corn, Wheat, and Sawdust. Ginger starch granules are egg-shaped with protuberances at one end. A mass of soft wood fibre appears at the top.

Fig. 13.—Wheat Starch. Circular granules of various sizes, many having concentric rings.

Fig. 14.—Pure Mustard. The fine granular masses are the mustard substance. The globular bodies are oil drops.

Fig. 15.—Mustard Adulterated with Wheat. Nothing but masses of wheat starch and bran appear in this field.

Fig. 16.—Rice Starch. Small sharply pointed polygonal granules.

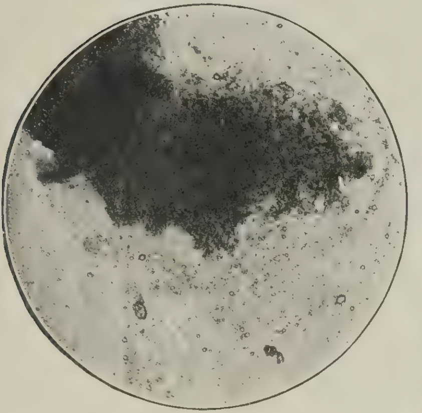

FIG. 9.—Pure Cloves.
× 130.

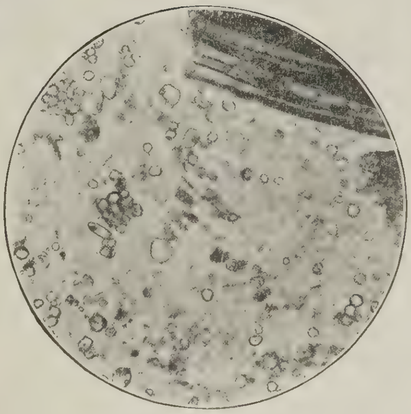

FIG. 12.—Ginger Adulterated with Corn, Wheat, and Sawdust.
× 130.

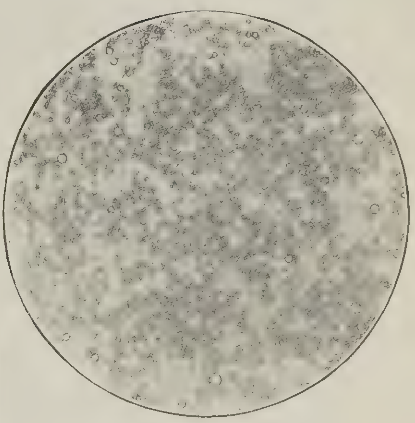

FIG. 14.—Pure Mustard.
× 130.

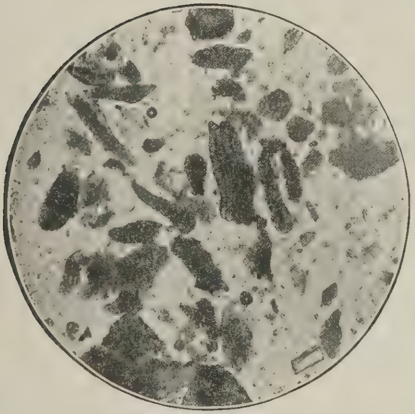

FIG. 10.—Cloves Adulterated with Cocoanut Shells.
× 130.

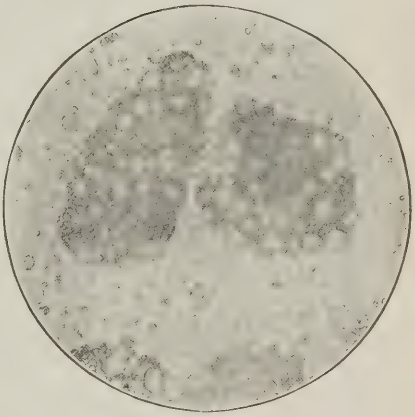

FIG. 15.—Mustard Adulterated with Wheat.
× 130.

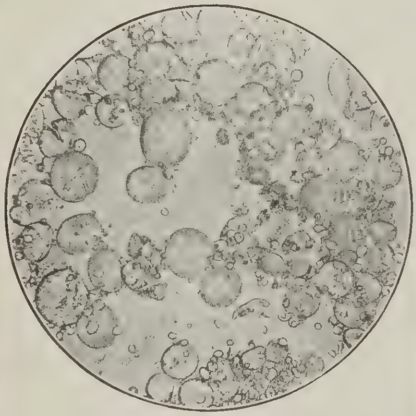

FIG. 13.—Wheat Starch.
× 220.

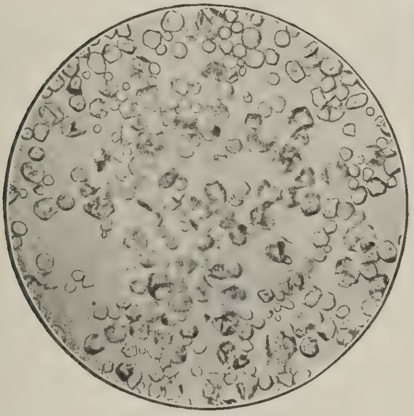

FIG. 11.—Corn Starch.
× 220.

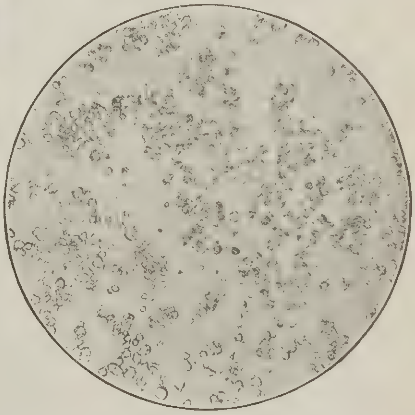

FIG. 16.—Rice Starch.
× 220.

PHOTOMICROGRAPHS OF PURE AND TYPICALLY ADULTERATED
FOODS AND ADULTERANTS

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use with butter and lard, is of great service in examining olive oil. The refracting degree of cotton-seed oil on the scale of this instrument is about 4.8° higher than that of pure olive oil at a given temperature. Peanut oil, which has been used as an adulterant of olive, has nearly the same degree of refraction as cotton-seed oil, while corn oil, found by the author in alleged olive oil, is at least 13° higher on the Zeiss scale than pure olive oil.

The presence of cotton-seed oil is best confirmed by the Halphen test described under Lard.

Spices.—Adulterants of spices are best detected by submitting them to microscopical examination. The finely ground sample is mounted by placing a small portion on a glass slide by means of a knife blade, treating with a drop of distilled water, and rubbing out under the cover glass between the thumb and finger. The specimen is best examined with a one-sixth-inch objective and a medium ocular, giving a magnification of from 240 to 330 diameters.

It is extremely difficult to describe the actual microscopical appearance of such composite substances as the spices. Each has its own particular characteristics, and the analyst should provide himself with a complete set of powdered pure spices, and of starches, ground olive and date stones, nut shells, bark, pea hulls, sawdust and other adulterants of known purity, and familiarize himself with their microscopical appearance, making his own standards for comparison. Plates XXVI. and XXVII. illustrate both pure and typically adulterated samples of some of the spices as they appear under the microscope. A few of the most striking features to be looked for in the common spices are as follows:

Allspice.—Small circular starch granules, often arranged in clusters; very striking amber-colored lumps of gum; a considerable quantity of stone cells, mostly colorless.

Cassia.—Small starch granules, intermingled with patches of yellow skin and bundles of brown and yellow wood fibres; stone cells, often of a brown color.

Cayenne.—No starch; yellow droplets of oil; patches of skin with striking markings not unlike the convolutions of the intestines.

Cloves.—No starch; occasional, though very few colorless stone cells; colorless oil drops; masses of spongy, brown cellular tissue of indefinite structure, but unmistakable; spiral ducts.

Ginger.—Large starch granules, egg-shaped with small protuberances at one end; colorless cellular tissue; masses of wood fibre.

Mace.—No starch; colorless oil drops; characteristic cellular tissue.

Mustard.—No starch; colorless oil drops; spongy, colorless cellular tissue with both yellow and colorless patches of hull, filled with brown spots.

Nutmeg.—Small, circular starch granules with central hila; colorless, indefinite cellular tissue.

Pepper.—Very minute starch granules; arranged in large masses; rectangular stone cells.

Tea.—The percentage of ash is a ready means of ascertaining whether or not any considerable amount of dirt or mineral matter has been added. Five grams of the sample are carefully burnt in a tared platinum dish to a white ash over a free flame at a low red heat, and the residue is cooled and weighed. The ash of a pure tea should not exceed seven and one-half per cent. If the ash is abnormally low, the presence of spent or exhausted leaves is indicated. Tea stems and fragments as well as foreign leaves are best recognized by soaking the leaves in boiling water, which opens them out so that their nature is readily apparent.

Vinegar.—Although the percentage of solids and acidity in cider vinegar are important factors in determining its purity and strength, standards being fixed for these in many localities, it by no means follows that a sample of cider vinegar high in both solids and acidity is pure.

Total Solids.—Five grams are weighed from a pipette into a tared platinum dish, which is then transferred to a boiling water bath and kept in contact with live steam for at least an hour and a half. It is then cooled and weighed, the residue representing the vinegar solids. If the solids have been reinforced by apple pomace, this is rendered apparent by burning the residue to an ash in the platinum dish and determining the weight of the ash. If the ash is less than six per cent. of the entire solids, there is no doubt that unfermented sugar-containing material has been added. The normal percentage of ash in total solids of pure cider vinegar should be at least eight and one-half.

Acidity.—This is commonly determined by titrating 6 c.c. of the vinegar with decinormal sodium hydroxide, using phenolphthalein as an indicator. The per cent. of acetic acid is exactly one-tenth of the number of cubic centimetres of the alkali required for neutralization.

It is possible to use lime water as a reagent in determining approximately the acidity of vinegar. A saturated solution of air-slaked lime has a nearly constant alkalinity. If 2.75 c.c. of vinegar are titrated against saturated lime water, the number of cubic centimetres of the latter required to neutralize, divided by ten, gives directly the per cent. of acetic acid very closely.

Reaction with Lead Acetate.—The *absence* of a precipitate with this reagent shows positively that the vinegar is not genuine, but a precipitate does not necessarily prove the vinegar to be pure.

The Polariscope Test.—A genuine cider vinegar should always polarize to the left of the zero point, a right-handed polarization being absolute evidence of adulteration, the adulterant often being in this case apple jelly containing glucose.

The vinegar sample may usually be sufficiently clarified for polarization in a 100 mm. tube by simply passing through a double filter.

Sulphuric Acid or Sulphates are indicated, if on the addition of barium chloride reagent to the sample, a precipitate is formed. *Albert E. Leach.*

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FOOD POISONS.—From the earliest times poisoning from diverse foods has attracted the attention of the laity and of medical men. Numerous explanations, many of these decidedly absurd as viewed from the standpoint of our present knowledge, have been put forth, and it is only within comparatively recent years that vague hypotheses have given way to exact chemical and bacteriological studies. As a result, a flood of light has been thrown upon the causation of food poisonings, and the observations thus made have in turn served their purpose of indicating the relatively simple means by which many of these intoxications may be avoided.

Individual susceptibility plays a most important part in all poisonings. It is very well known that a given poison may affect two individuals in a wholly different manner. Moreover, observations are not wanting which show that a substance which we may have good reason to consider as wholly innocuous is nevertheless very deleterious to some. The fortunately very rare instances of fatal results following the injection of antitoxic sera may be taken as an example of such idiosyncrasy. In like manner one may meet with individuals to whom a given article of food invariably plays the part of a poison, and justifies the oft-quoted adage that "what is meat to one is poison to another." The use of veal by some, and of eggs by others, is often followed by distressing symptoms. The cleavage products of such foods, whether due to defective metabolism or to a peculiar bacterial flora in the intestines, are in the main responsible for the ill effects experienced.

While idiosyncrasy has to do with a single individual, there are on the other hand hundreds of instances of "food epidemics" where an extraneous cause must be sought for. In the latter cases the food or article consumed has acquired in some way marked poisonous properties, and in so far as the origin of this poison is concerned it may be spoken of as *endogenous* or *exogenous*.

Those articles in which the poison is of endogenous origin can hardly be designated as foods, although it may be very convenient to speak of them as auto-poisonous. The poisonous mushroom, for example, is often mistaken for an edible form. The two kinds are wholly distinct, and the former is injurious because it normally produces a highly poisonous alkaloid, muscarine. In like manner the blood of eels is toxic, because of the presence of preformed physiological products. Some animals, especially molluscs and fish, are popularly believed to acquire poisonous properties at certain phases of sexual life. However, it is very certain that there are fish which when perfectly fresh are highly poisonous. Just as the poisonous mushroom is capable of elaborating its specific poison, so certain fish are similarly endowed and give rise to normal physiological but toxic products. The nature of the products elaborated in the tissues of such poisonous fish is not known. They are believed by some to be leucomains or basic alkaloidal substances formed by the peculiar cell metabolism. Intoxications which are due to fish which are poisonous in and of themselves are of common occurrence, especially in the West Indies and in Japan. It is to this class of poisonings that Blanchard has applied the term *siguatera*, to distinguish it from the more ordinary food poisonings of exogenous origin.

The exogenous origin of food poisons is by far the most common occurrence. Under this head are to be placed all those articles of food or consumption which are ordinarily perfectly wholesome and which only occasionally, and then through what may be designated as an accident, acquire injurious or poisonous properties. The poison or injurious element in such cases is of foreign origin, and it is because of the introduction and presence of such poison in a food that the unexpected manifestations of intoxication are observed.

The food poisons of exogenous origin may be discussed under three heads: (1) Poisonous metals; (2) animal parasites; (3) vegetable organisms, including bacteria and fungi.

With reference to the first head, that of poisonous metals, it may be said that they play as a rule only a very secondary rôle in outbreaks or epidemics of food poisoning. The metals which are supposed or have been shown to be the active cause of poisonings are arsenic, antimony, tin, lead, zinc, and copper.

An interesting instance in which arsenic and antimony were the cause of fatal poisoning in animals was noted several years ago by Vaughan. In a Western mining region where hydraulic mining was practised, the disintegrated ore deposit was washed down into a river, the water of which as a result became highly charged with soluble and suspended arsenic and antimony compounds. A much more notable instance, however, of poisoning of this kind is that recently (November, 1900) observed in Manchester, where a widespread epidemic of peripheral neuritis followed the use of beer which on analysis was shown to contain appreciable amounts of arsenic. The arsenic in this case was derived from the sulphur ores which were used in the manufacture of sulphuric acid. The latter, in turn, with its unknown arsenic contents, was employed in the preparation of the glucose, and it was through the glucose that the metal found its way into the beer.

Lead poisoning which follows the use of water which is conveyed through lead pipes is a well-known fact. An unusual instance of intoxication was reported in 1887 by Stewart. A Philadelphia baker ignorantly used lead chromate as a substitute for eggs to color his dough. The buns prepared with this material are known to have caused 64 poisonings, 8 of which proved fatal. A somewhat similar mistake is that reported many years ago by Ungefug, who found that a large quantity of zinc sulphate had been used in place of the preservative saltpetre.

In articles of food which have been kept for some time in tin cans, or in zinc or copper vessels, traces of these metals can be invariably expected, and while unquestionably these metals in large doses are poisonous, it is nevertheless true that they have little or nothing to do with the acute poisonings so often observed. The bare possibility of canned foods being poisonous as a result of the presence of these metals may be conceded, but the occurrence of such is very doubtful indeed. In such cases it can be shown that bacterial decomposition has taken place, and while it is possible for the organic acids produced by such decomposition to dissolve the metals, still true bacterial poisons may be present and should be looked for. This can be done only by studying the effects produced by pure cultures of the organisms present in such food.

Food poisoning as the result of the presence of animal parasites has been a recognized fact ever since the discovery of trichinæ in the flesh of hogs. It is very important in suspected poisonings when pork or pork sausage has been eaten, to make a careful search for trichinæ. This should be done before a chemical and bacteriological examination is undertaken. Like trichinæ, other animal parasites, notably those of the intestines, may be introduced with the food, but these occurrences are rarely considered under the head of food poisons, and for that reason need no extended consideration in this connection.

Vegetable organisms constitute by far the most common cause of food poisoning. It will be presently shown that certain moulds or fungi thriving especially on plant food may render these injurious. Apart from these isolated and in this country largely unknown intoxications, it may be said that bacteria are the only type of vegetable life which are concerned in the vast majority of food infections. Dead animal or vegetable matter is prone to invasion by bacteria, and putrefaction or fermentation, as the case may be, is soon established. To use an axiom of Claude Bernard's, "death is life," and the life thus established in dead matter under favorable conditions is seen in the myriads of the tiny workers, whose duty it is to break up and transform the complex organic substances present in plants and animals and return their elements to the inorganic world. The bacterial invasion of wounds finds its analogue in the bacterial invasion of foods, and just as cleanliness and asepsis obviate the former, so proper storage and thorough cooking will prevent the latter. Of the large number of different kinds of bacteria which may find lodgment in a wound only a few perhaps are capable of producing poisonous products. This fact is likewise true of those bacteria which invade dead plant and animal matter. The mere fact that a food, solid or liquid, contains enormous numbers of bacteria does not indicate that it is poisonous. The vast majority of bacteria are harmless organisms which elaborate simply non-poisonous products. On the other hand, a relatively small number of bacteria are capable of making poisonous products, and to these organisms the term *toxicogenic* may be applied.

Inasmuch as bacteria, when injurious, produce their ill effects by means of the poisons which they elaborate, it is desirable briefly to touch upon these products. The term *ptomaïn* was introduced a quarter of a century ago by the Italian chemist Selmi to designate basic alkaloidal products formed in putrefaction. Bearing in mind the fact that strychnine and muscarine are intensely poisonous vegetable alkaloids, it was quite natural to explain the profound intoxication met with in infectious diseases and in the poisoning from foods by assuming that bacteria elaborated similar toxic alkaloidal products. It is largely through the labors of Brieger that our knowledge concerning ptomaïns was gained. A considerable number of these basic alkaloidal products were isolated. The mytilotoxin found in poisonous mussels is of this class and is by far the most poisonous of the known ptomaïns. As a rule these substances are but feebly poisonous or not at all, and it follows that in such instances some other poison non-basic in character must be present. The term "ptomaïn poisoning" has been popularized to such an extent that it is used synonymously with food poisoning. The fact is that in only very exceptional instances are ptomains to be credited with being the cause of such poisoning.

The study of snake venom showed that the active poison in that secretion was an albuminous substance. Like investigations made with the seeds of jequirity and with the castor bean showed the presence of other poisonous proteid bodies. Brieger and Fraenkel in 1889 examined highly poisonous diphtheria cultures, and from these they obtained very poisonous precipitates which being proteid in composition were designated as *toxalbumins.* The same method of examination soon revealed the presence of toxalbumins in cultures of other disease-producing bacteria. In a very short time, however, it was shown that the so-called toxalbumin was not a definite chemical substance but rather a mixture of an inert proteid and an active poison non-proteid and non-basic in character. To distinguish the real poison from ptomaïns and from the so-called toxalbumins it has been designated as the *toxin.* After all, this is merely a term for an as yet unknown or rather but as yet imperfectly known substance. The toxins of diphtheria and of tetanus have been studied the most, but beyond a general knowledge of their reactions and behavior nothing is known as to their structure or composition. One thing is certain, that in the toxin many bacteria possess a most deadly weapon. Brieger and Cohn, after purifying the tetanus toxin, for example, as much as possible, found that the extremely minute amount of 0.00000005 gm. killed mice. A similar and almost equally destructive toxin has been separated from cultures of the Bacillus botulinus obtained from some poisonous ham. This product will be presently discussed at some length.

Recognizing the fact that bacteria are the cause of the majority of food poisonings and that they induce their poisonous effects by means of the toxins which they elaborate, it is of interest to inquire into the formation of these products. While many toxicogenic bacteria, especially including the disease germs, are capable of growing at the temperature of the body, there are those which cannot do so. The latter are therefore incapable of growing in the body. The poisons which such organisms elaborate must of necessity arise in the food, while this is kept at the ordinary room temperature. The effects which follow the eating of such food will necessarily vary directly with the quantity of the food taken, since the active poison is made wholly outside of the body. Ballard's Iron Bridge cases are instances of this kind of poison production, for in these the specific germ would not grow above 86° and its cultures at 60° were markedly poisonous. The same is true, as will be presently shown, in poisoning with food which contains the B. botulinus. The organisms at work in such cases, although toxicogenic, are nevertheless practically obligative saprophytes. Poison production then may take place (1) wholly outside of the body. On the other hand, (2) given an organism which is capable of growing at the body temperature as well as at the room temperature—in other words a facultative parasite,—it follows that such an organism, having begun the production of poison outside of the body, in the food, may continue to elaborate like poisons in the intestines after such food is taken. While in the first instance the effects are those of a plain intoxication following the introduction of a ready-made poison, in this case intoxication and infection are combined. A third type of poison production is shown when the organism present in the body is truly pathogenic. It may be present in but very small numbers in the food and the poisonous products made therein may be practically nil yet disease may follow. In other words, a true infection results from the presence in the food of disease-producing organisms. Contamination of drinking-water or milk with cholera or typhoid bacteria would fall under this head. More directly, however, this group will include bacterial diseases of animals which may be transferred to man through the flesh of animals so diseased. This type of food poisoning, it will be seen, is analogous to that with animal parasites. A number of well-defined instances of this kind will be presently given.

From what has been said it is evident that the greater part of food poisonings are instances of food infection. Such food either was at first perfectly wholesome and through improper handling became contaminated with poison-producing bacteria; or, derived from diseased animals, it already contains the specific harmful germ. In view of the undoubted fact that the germs producing these poisons are very rarely the same in two distinct outbreaks, it follows that the poisons are different and as a consequence the symptoms observed will vary within very wide limits. It is not reasonable or in accordance with known facts to believe that in poisonous cheese, for example, only one and the same organism is always present and that the chemical poison is the same in all intoxications from such food. A considerable number of organisms undoubtedly, if the opportunity is given for their development in cheese, are capable of rendering it poisonous. In like manner, poisonous meats, sausage, and fish do not owe their toxicity to any one specific organism. Already a number of toxicogenic bacteria have been isolated during the past ten or twelve years from different outbreaks of meat poisoning. This number will of necessity be increased as more careful methods come to be employed in the study of these accidental poisonings.

POISONOUS MEAT.—Every kind of meat which man is accustomed to use as food is liable to become poisonous. Raw or improperly cooked meat is usually responsible for the occurrence of such results. The frequent occurrence of sausage poisoning in Germany led to its designation as botulismus or alantiasis. These terms, however, may be used so as to embrace any meat poisoning, but it is preferable to retain the original meaning of botulismus and following the nomenclature of Vaughan to designate meat poisonings, regardless of form or origin, as *Kreotoxismus.*

Bacillus Botulinus.—By far the best studied instance of meat poisoning is that recorded by Van Ermengem. The outbreak occurred in the Belgian village of Ellezelles and at first affected thirty-four persons who were all members of a musical society. A few days later a number of other persons became sick with the same symptoms. Three of the persons afflicted died within a week. The investigation which took place showed that the sick people had all partaken of a certain ham. The hog from which the meat was prepared was perfectly healthy and at the time of slaughtering a portion of the meat was eaten raw without any effect following. After salting, both hams and other portions of the animal were packed away. The brine used was clearly deficient in salt and insufficient in quantity, since only the bottom ham was immersed in the liquid. The upper portions of meat were consumed without any ill effect and it was only the immersed ham which caused the poisoning. This exclusion of air as well as the deficiency of salt allowed the development of an anaërobic bacillus to which Van Ermengem applied the name B. botulinus. It may be remarked in passing that Kempner obtained the same organism from the fæces of a hog.

The symptoms observed in this outbreak were shown to be due to a toxin elaborated by the bacillus in the ham. The lateness in the onset of the symptoms and the absence of fever were rather remarkable for a true intoxication. As a rule no effects were observed during the first twenty-four hours after the meal and in some cases the onset was delayed for thirty-six hours. Gastric pains with repeated vomiting were first observed. With the exception of two cases all had an obstinate constipation. The gastro-intestinal symptoms were not so marked as in most instances of food poisoning, but the nervous symptoms were especially pronounced. All showed characteristic disturbances of vision. The eyes became fogged and in a short time recognition of people failed. Diplopia set in. Marked dilatation of the pupils with total loss of reaction as well as ptosis of both eyelids followed. Added to this was the sensation of a burning thirst and a constriction of the throat. The latter at times was so marked as to render the swallowing of even liquids difficult. The mucous membranes were strongly reddened, and in some the abundant secretion of viscid mucus led to violent attacks of coughing and even of suffocation. At times complete aphonia and anuria were observed. Extreme muscular weakness was general. In spite of these severe symptoms the pulse remained below 90, the respiration and temperature were normal. In fatal cases coma or mild delirium occurred. The recovery was very slow and extended through several weeks and even months.

Feeding of the ham or of macerations made with it proved fatal to mice, white rats, young cats, guinea-pigs, and monkeys. Subcutaneous injections of 0.001 c.c. of the maceration (1 to 5) killed mice. In larger doses it was fatal to rats, doves, and cats. Rabbits were extremely susceptible, while frogs, dogs, and chickens were refractory. The fact that the maceration after being filtered through porcelain was as active as when unfiltered showed that a soluble toxin existed in the ham. The further fact that the bacillus was not present in the organs of the animals that died after inoculation showed that it was a true saprophyte, although markedly toxicogenic.

The toxin of B. botulinus in its activity resembles that of tetanus or diphtheria. It is promptly destroyed by boiling but not by putrefaction. Marinesco found that the lesions produced by this toxin are largely confined to the cells of the gray matter of the cord. With very small doses the lesions consist of a rarefaction of the chromatophil elements. Under the influence of larger amounts of poison the granules of Nissl undergo more or less marked disintegration or chromatolysis. When fatal doses are administered some of these cells will be found to be completely destroyed. Kempner has successfully immunized a goat against the action of the toxin and obtained an antitoxic serum of marked potency.

Non-febrile intoxications with pronounced nervous symptoms accompanied by obstinate constipation have been repeatedly observed in the past in connection with sausage poisoning, and it is quite possible that a similar, if not identical, toxin to that just described was the cause. A noteworthy instance of this kind was furnished by the observation of von Faber, who reported in 1821 an outbreak which caused the death of five out of sixteen people who had eaten fresh unsmoked pork sausage. There were constriction of the throat, difficulty in swallowing, retching, vomiting, colic-like pains, vertigo, hoarseness, dimness of vision, and headache. Later on, in the severe cases, there was complete exhaustion, and finally paralysis. The eyeballs were retracted, the pupils were sometimes dilated, then contracted, and did not respond to light. The upper lids were paralyzed. The tonsils were swollen, but not as in tonsillitis. Liquids which were not irritating could be carried as far as the œsophagus, when they were ejected from the mouth and nose with coughing. Solid foods could not be swallowed. On the back of the tongue and in the pharynx there was observed a puriform exudate. Obstinate constipation existed in all, while the sphincter ani was paralyzed. Breathing was easy, but all had a croupous cough. The skin was dry and there was no incontinence of urine. There was no delirium and the mind remained clear to the last.

As a rule, however, intoxications resulting from sausage and other foods are characterized by a febrile gastro-enteritis. Thus, in the Wellbeck cases reported by Ballard the temperature at times rose to 103° and 104° F. and the diarrhœa was quite unrestrainable. Muscular weakness was an early and marked symptom and the debility of convalescence was in nearly all cases protracted to several weeks. Intense and distressing thirst with nausea and vomiting was quite general. Ballard has described several additional outbreaks of food poisoning which it is scarcely necessary to dilate upon.

Bacillus Enteritidis.—This name was applied by Gärtner to the organism which he isolated in 1888 from meat which had poisoned a large number of persons. The same organism was also isolated from the spleen of a man who died from the effects of the meat poisoning. The meat was unquestionably infected from the beginning, inasmuch as the cow which furnished it had a severe diarrhœa for some days before she was killed. Of the fifty-eight people who were rendered sick one died. The effects observed were those of a pronounced gastro-enteritis with subsequent desquamation. These symptoms occurred in persons who had eaten the cooked meat as well as in those who had taken it raw. On feeding animals with sterilized cultures of this bacillus Gärtner was able to show that such cultures were highly poisonous. Guinea-pigs thus fed died in anywhere from a few hours to five days. Mice similarly fed died in a few days. It is noteworthy that unlike Van Ermengem's toxin, which is readily destroyed by heat, the cultures of Gärtner's bacillus maintain their toxicity even after boiling for several hours. The poison then is very resistant to heat and resembles in this respect the intracellular toxins of the colon bacillus which have recently been studied by Vaughan. Morphologically the Bacillus enteritidis is closely allied to the colon bacillus, from which, however, it differs in not producing indol and in its pronounced infectiousness even when fed to animals.

The same organism, or at all events one closely allied to it, was isolated in 1891 by Lubarsch from the lungs and spleen of a child who died of what was diagnosed as Winckel's disease. Karlinski has also succeeded in isolating this bacillus from a case of food poisoning which came under his observation. Fischer likewise met with what he believed to be Bacillus enteritidis in an outbreak of food poisoning which affected nineteen persons. The vomiting and violent purging observed were traced to the meat of a sick cow which had recently calved.

In a case of food poisoning studied by Johne the B. enteritidis was also found. The same organism has also been met with in all probability by Poels and Dhont, Holst, and Günther and it would therefore appear that this bacillus is widely distributed in nature. The food poisoning reported by Günther in 1897 affected some twenty-six or twenty-seven families and was due to the eating of pork, as well as to the sausage and blood derived from the same. Abdominal pains, vomiting, diarrhœa, and extreme weakness were the symptoms observed. Only one person died, and from the internal organs of this individual Günther isolated the B. enteritidis. It was assumed that this organism was present in the poisonous food, but all efforts to isolate it from the latter failed.

Another instance in which presumably the B. enteritidis was involved is that observed by Silberschmidt in 1896. A small outbreak resulted from the use of the smoked meat of a suckling pig which was diseased when killed. The symptoms were essentially the same as those just given, and one death resulted. Those who had eaten cooked meat were also affected, although boiled extracts of the meat had no effect on animals.

Bacillus Morbificans Bovis.—The organism thus designated by Basenau was obtained from the meat of a cow which was slaughtered while suffering from puerperal fever. Subsequently he isolated the same organism from the meat of animals sick with perforative peritonitis, puerperal paralysis, and chronic pyæmia. The germ proved to be very infectious to the ordinary experimental animals. On the other hand it is by no means certain that the organism is toxicogenic with respect to man. It is more than probable that it is nothing more than a variety of the colon bacillus.

Bacillus Breslaviensis was found under conditions similar to the preceding in several distinct outbreaks. According to Van Ermengem food poisonings in Morseele and in Ghent in 1892 and in 1895 yielded this bacillus. In the Morseele outbreak the cause was found in the flesh of two calves that died of an undoubted infection. Of the eighty people rendered sick four died. The symptoms were those of pronounced gastro-enteritis accompanied by a high fever. In severe cases ecchymoses of the skin and disturbances of vision, while in children convulsions were observed. The outbreak in Breslau was studied by Kaensche in Flügge's laboratory. In this case also the meat was derived from a diseased cow which was killed while suffering from a high fever and a severe diarrhœa. No deaths occurred, although some eighty people were affected. Taken as a whole, the descriptions of the organisms met with in these cases agree very closely, and it is quite probable that the same germ was present in each. It is to be noted that the cultural and morphological properties of this germ are essentially those of the colon bacillus. Unlike the latter, however, it does not make indol or coagulate milk. An important feature is the fact that the poison is not destroyed by heat, and in this respect it agrees with Gärtner's B. enteritidis. Boiled or unboiled cultures or infected meat, when fed to or injected into mice and rabbits, caused death, while dogs and cats were wholly unaffected.

Bacillus Friedebergensis.—Kruse has thus designated the bacillus which Gaffky and Paak described in 1890. The source was some sausage made from the flesh and livers of several horses. The sausage was prepared in a most careless manner and as a result showed putrid decomposition. More than thirty persons were poisoned by eating this sausage and one of these died. The onset of the symptoms occurred in a few within half an hour, as a rule within six hours, although some were not affected for twelve to twenty-four hours. A marked chill, headache, abdominal pains, loss of appetite, nausea, vomiting and diarrhœa were present. As in other instances of food poisoning muscular weakness was pronounced and many were therefore unable to resume work for many days. Dizziness, thirst, and fever were also observed, but apparently no disturbances of vision. The injection subcutaneously of macerations of the sausage proved fatal to rabbits, guinea-pigs, and mice, and from these animals a short bacillus was recovered. A single feeding of sausage to mice caused the death of one in eight days and in it the same bacillus was found. Gaffky and Paak considered this organism to be responsible for the effects observed in man. The pure cultures, when given by the mouth or injected subcutaneously or intravenously, proved fatal to animals. Unlike those of B. enteritidis the cultures when boiled lost their toxicity. Like the preceding organism this one does not give rise to indol nor does it coagulate milk. Otherwise it resembles very closely the colon bacillus and may be considered to be a variety of the same.

From cooked meat which caused an outbreak of diarrhœa in Utrecht in 1896, Hamburger isolated a non-motile bacillus to which he gave the name *B. cellulæformans.* The organism did not liquefy gelatin and when grown in bouillon it produced a heavy scum but little or no cloudiness of the liquid. The infected meat when fed to mice proved fatal.

In 1897 Pouchet reported a case in which forty-nine people were poisoned by eating spoiled pork. Headache, dizziness, vomiting, diarrhœa, and fever with a general erythema were observed in those affected. Pouchet isolated an organism which he considered to be the same as the hog cholera bacillus of Metschnikoff. Inasmuch as the germ studied by the latter was really that of swine plague and not of hog cholera, it is probable that the swine-plague germ was responsible for this poisoning. It is interesting to note in this connection that Lubowski (1901) has succeeded in isolating the bacillus of hog erysipelas from the intestines of an icteric child, and it is not unlikely that in this instance infection took place through the food. There are undoubted instances in which anthrax has been conveyed to man in this way.

Ballard has reported a number of outbreaks of meat poisoning. Beef, canned pig's tongue, jellied pig's head, pork, ham, veal pie, pork pie, and canned sardines were the respective causes in these several outbreaks. It is interesting to note that the "Middlesborough pneumonia epidemic" which caused four hundred and ninety deaths, is attributed by Ballard to poisoning with imported bacon. He believed that the disease developed in a person who had eaten of the infected food and was transmissible from the sick to those who had not partaken of the infected food. In the lungs Klein found a short, thick bacillus which he called Bacillus pneumoniæ. This germ was different from the bacillus of Friedlaender and from the diplococcus of Fraenkel. Fourteen out of the twenty samples of bacon when fed to rodents produced death with lesions similar to those observed in man. During the progress of the investigation an epidemic of pneumonia broke out among the animals and in these the same organism was found. The poisonous bacon when kept for three months lost its toxicity and no growth of the bacillus could be obtained.

In 1894 Vaughan and Perkins examined some dried beef which had quite seriously poisoned a family of four. There was nothing in the appearance or odor of the beef to cause any suspicion. In fact it seemed to be of exceptionally good quality. Anaërobic cultures from the interior of the meat gave a colon-like bacillus which was pathogenic to white rats, rabbits, and guinea-pigs. The sterilized cultures were also poisonous. In an outbreak which occurred in Sturgis, Michigan, in the same year, a large number of men were rendered ill after partaking of pressed chicken. All were taken, within two to four hours after eating the chicken, with nausea, violent griping and purging, many fainted while attempting to rise from bed. From the food Vaughan and Perkins isolated a slender bacillus and a streptococcus. The former proved to be very fatal to experimental animals. Anaërobic cultures were much more powerful than aërobic ones.

During the past few years a number of food poisonings have been investigated in which the causative organism has been shown to be in all probability the *Proteus vulgaris* or its related species. Thus Levy, in 1894, investigated a case of this kind. The keeper of a restaurant and some of his guests suffered from a most violent purging, which in the case of the host terminated fatally. Proteus vulgaris was isolated from the vomited matter, from the stools, and from the ice-box where the food was kept. Levy sought to demonstrate that the poison in this case was identical with the sepsin of Schmiedeberg. Wesenberg in 1897 studied a food epidemic which affected sixty-three persons. The suspected meat came from a cow that was slaughtered when sick. Violent headache, intense abdominal pains, dizziness, extreme muscular weakness, and diarrhœa were the symptoms noted. The greenish or brownish discharges were very putrid. The more or less decayed meat yielded a bacillus which Wesenberg believed to be identical with Proteus vulgaris. It remains a question, however, whether this germ was the actual cause of the intoxications.

Silberschmidt reported similar results from an epidemic which occurred in a Swiss canton in 1899. In this instance forty-five persons were affected and one death resulted. The symptoms came on within twenty-four hours after eating "Landjäger" sausage, made out of beef and pork fat. The animals were apparently perfectly healthy. The taste and appearance of the sausage were faultless. Cultures made from the sausage gave B. coli and Proteus vulgaris. The etiological relation of the latter organism to the poisonings was by no means clearly demonstrated.

A somewhat similar outbreak was investigated in 1900 by A. Pfuhl. A "beef sausage" made by chopping up finely and potting the entrails, hearts, lungs, and spleens of three cattle was the cause of an acute gastro-enteritis in eighty-one soldiers. The material fed to rats and mice induced diarrhœa, and gradual paralysis of the limbs, but the animals recovered. One of the mice was killed and from it Pfuhl isolated a bacillus which he identified with

Proteus mirabilis. Pure cultures of the germ fed to mice caused death whereas rats recovered. The organism when inoculated into fish formed capsules but not otherwise. The toxin was destroyed on heating to 60° C. The dead bacilli were shown to be as toxic as the living, indicating that the poison was largely intracellular.

In the above instances the demonstration that the poisoning was due to the Proteus group is far from perfect. There is no question but that these organisms are toxin producers, but that fact and the detection of such organisms in a food does not prove that they are the cause of the poisonings observed. Nevertheless, it may be well to indicate that at times proteus infections have been met with in man and that several observers have ascribed epidemics among fish to this same group. These will be presently touched upon.

Poisonous Fish.—In those countries where fish is the chief form of animal food it not infrequently gives rise to severe outbreaks of acute poisoning. Just as sausage poisoning is of relatively frequent occurrence in Germany so fish poisoning in Russia is equally common. In this country poisoning from canned fish has been repeatedly observed. As in the case of meat, fish may become poisonous as a result of being diseased; or, improperly preserved, the otherwise wholesome fish may become infected with saprophytic toxicogenic bacteria. In the one case the organisms are present during life and in the other they are introduced after death. On the other hand it is well to remember that some fish are always poisonous either as the result of the presence of poisonous glands or as a result of eating certain kinds of food, while others may become poisonous during the spawning season. In such instances the toxic condition is normal and physiological. It is this form of poisoning which is designated by the Spanish physicians of the West Indies as *siguatera*, to distinguish it from the bacterial poisoning or botulismus. It is preferable, following the classification of Vaughan, to designate fish poisoning as *ichthyotoxismus*.

Epidemic diseases among fish have been observed by a number of investigators. Thus Charrin, in 1893, isolated several organisms which were pathogenic to fish. Emmerich and Weibel in the following year described the Bacillus salmonicida as the cause of an epidemic among trout. Sieber, in 1895, found that the fish in an aquarium, from which some had been taken to supply a table and had proven poisonous, were sick and that as many as thirty died within the next two days. From the dead and sick fish she isolated a highly toxicogenic germ to which she has given the name Bacillus piscicidus agilis. From cultures of this bacillus she isolated cadaverin and other known ptomaïns, besides which at least two undetermined bases were present. Sieber found the same germ in the dejections of two cholera patients. In 1898 Wyss reported the results of his study of an epidemic which prevailed among the fish in Lake Zurich. From the diseased fish he isolated an organism which he believed to be identical with Proteus vulgaris, although there were slight differences, such as the non-coagulation of milk, and non-decomposition of urea. Moreover, Wyss believes that the above-mentioned Sieber's bacillus is identical with that isolated by him and hence is also a Proteus vulgaris. That fish infected with this germ, if eaten in a partially cooked state, may cause poisoning in man is seen in Sieber's observation, and in the fact that proteus infections of meat have been described by Levy, Wesenberg, Pfuhl, and Silberschmidt.

Arustamoff, in 1891, observed eleven cases of fish poisoning, five of which proved fatal. The imperfectly salted fish contained enormous numbers of bacteria which formed typhoid-like colonies. The symptoms were general weakness, dull pain in the abdomen, dyspnœa, mydriasis, vertigo, and dryness of the mouth. It is probable that diseased fish were packed away with wholesome ones and, as a result, the entire mass became eventually infected. Cooking destroyed the toxicity of the fish.

According to Schmidt the fish poison is an animal alkaloid, a ptomaïn, produced most probably by bacteria that cause an infectious disease in the fish. Anrep partially isolated two active ptomaïns from poisonous fish. One of these was extracted from alkaline solution with ether, chloroform, and benzin. It was fatal to rabbits in doses of 0.5 mgm. A somewhat similar ptomaïn was isolated by Kakolew. From our present knowledge of bacterial poisons it is quite certain that the real toxic principle in poisonous fish, like that of Bacillus botulinus, of tetanus or of diphtheria, is not a basic product but is rather a non-proteid toxin.

Ballard reported fatal poisoning following the use of canned salmon. The can was "blown" and the contents were partially decomposed. The one who ate the most was attacked about ten hours after eating and died in three days. One who ate less became ill in about twelve hours and died in five days, while three others recovered. Klein found in both fatal cases necrosis of the mucous membrane of the stomach, fatty degeneration of the liver, and inflammation of the kidneys. Mice fed upon the salmon died, but no germs could be found in their blood. Evidently, as in Van Ermengem's case, a powerful toxin was produced by a mere saprophytic organism.

Another instance of poisoning from canned salmon is that reported by Vaughan. In this case the patient suffered from nausea, vomiting, and a griping pain in the abdomen; six hours later he vomited at frequent intervals small quantities of bile-colored mucus. Constipation was present and a scarlatinous rash appeared, covering the body from head to foot. The pulse was 140 and the temperature 102° F. Although the rash disappeared next day, a slight fever persisted for some time and the patient was confined to his house for a week. From the salmon Vaughan isolated a micrococcus which proved highly toxic when grown under anaërobic conditions.

Poisonous Milk.—Milk is unquestionably a most prolific source of intoxication and especially of real infection. This is readily understood when it is remembered that raw milk, the form in which it is most often consumed, contains enormous numbers of bacteria. Under most exceptional conditions a disease of the animal may be transferred through the milk which it secretes. As a rule, however, large numbers of bacteria from all imaginable sources enter the milk after it leaves the animal. More or less fermentation, even if no change is recognizable by the eye or taste, exists necessarily in such a product. The diarrhœas of infancy only too often stand in the same relation to milk as do the forms of gastro-enteritis resulting from the use of infected meats. Again, the transmission of typhoid fever through milk is known to have occurred. Thus Davies, in 1897, reported an outbreak of 197 cases of typhoid fever, all of which were directly traceable to one milk supply. Wilckens, in 1898, reported upon a similar epidemic which developed in Hamburg. Of the 82 cases unquestionably resulting from milk infection 65 were in women and children and only 17 were in men. However, by milk poisoning, or galactotoxismus, usually is meant acute intoxications analogous to those noted in connection with meat and fish.

The *tyrotoxicon*, discovered by Vaughan in 1885, first in cheese and later in milk, has been repeatedly found in milk and other milk products since then. Newton and Wallace in 1886 reported an outbreak of milk poisoning of this kind which affected a large number of people at Long Branch. In the same year Schearer found tyrotoxicon in milk used by, and in the vomited matter of, persons made sick at a hotel in Corning, Iowa. In 1887 Firth, an English army surgeon stationed in India, reported an outbreak of milk poisoning among the soldiers of his garrison, and from the milk he isolated tyrotoxicon. In the same year Vaughan reported an instance of milk poisoning, due to tyrotoxicon, in which three of the patients died. In 1898, Wesener and Rossmann reported the isolation of tyrotoxicon in crystalline form from poisonous cheese.

In view of the large number of different species of bacteria which may be present in milk it is evident that diverse organisms may take the causative rôle and hence different toxins may be elaborated in milk. Gaffky, for example, reports an instance in which three laboratory men became infected through milk, and suggests that the epidemic which prevailed in Christiania in 1888, in which six thousand people sickened within three weeks, was probably due to milk infection. From the former instance Gaffky isolated a small, highly virulent form of the colon bacillus.

Poisonings from various products of milk such as ice-cream, cream-puffs, and frozen custards have been frequently met with. In such cases undoubtedly the injurious organism is derived from the milk and with favorable conditions is enabled to multiply and give rise to its peculiar toxin. Here again no one organism is at work in all poisonings of this kind and consequently diverse poisons are to be expected. Coloring matter and especially flavoring extracts, such as vanillin, are often credited with causing these poisonings, but it can be readily shown that large quantities of such extracts can be taken without the least injury. While it is possible for deleterious substances or poisonous metals to find their way into milk, ice-cream, and other products, yet such instances have not been demonstrated. On the contrary a careful examination of such poisonous matter will invariably demonstrate the presence of toxic bacteria and their products.

In poisonous ice-cream, Vaughan and Novy repeatedly found tyrotoxicon, and this toxic bacterial product has been likewise detected in similar material by Schearer, Allaben, and Welford. In 1896, Vaughan and Perkins reported upon an outbreak of ice-cream poisoning which affected many people. Nausea, vomiting, and diarrhœa were as a rule present and the most alarming feature was the feebleness in the heart's action. In some persons the entire body became cool and clammy and the radial pulse was not detectable. In some delirium and stupor were also present. The germ isolated from the ice-cream showed a marked resemblance to the colon bacillus.

Cheese poisoning, or tyrotoxismus, like sausage poisoning is of relatively frequent occurrence and for that reason both attracted the attention of scientists at an early date. It is unnecessary to recapitulate the various theories that have been propounded from time to time to account for this toxicity of cheese. The phenomenon is readily explained along the lines heretofore laid down. Various toxicogenic bacteria may accidentally develop during the ripening or storage of the cheese and consequently impart to it poisonous properties. To Vaughan is due the credit of being the first to discover and isolate the chemical poison tyrotoxicon, in several outbreaks of cheese poisoning. Wallace, Wolff, and others have also isolated the same poison from cheese. Dokkum, employing a modification of the method used by Vaughan, isolated a somewhat different substance to which he gave the name tyrotoxin. From poisonous cheese Le Pierre obtained a basic body, $C_{16}H_{23}N_2O_4$. Insufficient attention has been given in the past to the study of the bacteria present in toxic cheese, and it is to be hoped that in the future special attention will be directed to this work. The studies of Vaughan and McClymonds have shown that toxicogenic germs are present in nearly all cheese. Cultures obtained from forty-nine samples of American green cheese killed white rats, guinea-pigs, and rabbits. The colon group is usually thus represented, and it is therefore a matter of little surprise if under favoring conditions some of these organisms develop sufficiently to render a given sample poisonous.

POISONOUS MOLLUSCS.—Mussel poisoning, or mytilotoxismus, is characterized by a greater variety of symptoms and a relatively greater fatality than is observed in other food infections. There can be no question as to the main fact that poisonous mussel owe their toxicity to the presence of bacteria and more especially to the products elaborated by these organisms.

In general three types of symptoms have been noted. A gastro-enteritis, characterized by nausea, vomiting, and diarrhœa, shows no difference from many of the common instances of meat poisoning. The exanthemic type has been most frequently observed. This begins with a sensation of heat which spreads from the face to all parts of the body and is followed by a papular or vesicular eruption. Itching is a marked feature and dyspnœa may be pronounced. The third type is very similar to that observed by Van Ermengem in connection with the Bacillus botulinus which he isolated from ham. The symptoms on the part of the nervous system predominate. Headache, dizziness, constriction of the throat, difficulty in speech, extreme muscular weakness, and numbness and coldness of the limbs are marked symptoms. The pupils are dilated and reactionless, but the pulse is relatively low and there is no elevation of temperature.

In recent years the best studied outbreak of mussel poisoning was that of Wilhelmshaven. In this case the cooked mussels produced symptoms within an hour or more and death resulted in two, three, and five hours after eating. From these mussels Brieger obtained the highly poisonous ptomaïn *mytilotoxin*. The fact that the poisonous mussel were obtained from brackish water and that they became non-poisonous when removed to fresh sea-water would indicate that the mussel were either diseased or their vitality was lowered to such an extent that they allowed the free development of toxicogenic bacteria.

Instances of poisoning with oysters are frequent enough. This is especially true when the oysters come from a bed polluted with sewage. Just as polluted milk or water may be the carrier of typhoid fever, so likewise oysters when gathered from polluted banks can, and have been known to, cause epidemics of this disease as well as less dangerous diarrhœas. At times the symptoms of acute intoxication following the use of oysters are as pronounced and as fatal as those noted in connection with mussel poisoning. Brosch, for example, reported a case in 1896 in which an officer died in twelve hours after eating some oysters which at the time were noted to have a bad taste. The symptoms were of the paralytic type: dimness of vision, salivation with inability to swallow or expectorate, anuria, difficult and indistinct speech, with paralysis of the right side of the face, including dilatation of the pupil and ptosis of the right eyelid, great muscular weakness, cyanosis and death.

POISONOUS VEGETABLE FOODS.—Although animal foods are most often the cause of food poisoning, yet they are by no means alone in this respect. Canned vegetable foods, tomatoes for example, have been known to give rise to serious illness. The presence of toxicogenic bacteria or of their products is responsible for these effects rather than are the traces of tin or lead which may be present. Instances of slimy bread which, as is well known, are due to the presence of slime-producing bacteria of the potato bacillus group, have been shown by Vogel to cause at times marked symptoms of gastro-enteritis.

Under the designation *sitotoxismus* Vaughan includes all forms of poisonings with vegetable foods, infected with moulds and bacteria. Mould infections especially play a most important part in vegetable foods, whereas they are practically unknown in connection with food of animal origin. The best-known example of this kind is ergotismus, veritable epidemics of which have prevailed in different parts of Europe during past centuries. At present, examples of this form of intoxication are relatively rare and are practically unknown in this country. The cause is the fungus, Claviceps purpurea, which develops on rye and other grain. At least three poisons, ergotinic acid, sphacelinic acid, and cornutin, are known to be present in ergot.

The disease known as pellagra, which prevails to an unfortunate extent in Northern Italy and in Spain, is due to a similar cause. The food in this case is corn which has been altered presumably by the action of moulds. Some investigators have credited bacteria with being the cause of this alteration, but this is by no means certain. Beri-beri, the well-known disease of Japan and of other islands in the Pacific, is commonly ascribed to the use of damaged rice.

Examination of Poisonous Foods.—A description of the various kinds of food poisonings would be incomplete without some statement of the methods to be pursued in making examinations of suspected material. It not infrequently happens that the amount of food that is left over from a meal is very small and for that reason it should be put to the best possible use. Inasmuch as a chemical analysis is of very little value it is not advisable to use up the greater part of the material in such work. At all events it should be deferred until a complete bacteriological examination has been made. The chemical substances will in no wise suffer by such delay.

A considerable amount of time can be saved, and perhaps wrong conclusions avoided, by determining at the outstart whether or not the suspected food is really poisonous. This is apparently a simple proposition but not always one that can be easily carried out. Some animals are not susceptible to a given poisonous food, while others are. Consequently, as many different animals as possible should be fed or given, through a stomach tube, the material under investigation until some are found to be susceptible. In comparatively mild poisonings the experimenter has been known to make the crucial test on himself.

In the case of pork and its products the presence or absence of trichinæ should be determined at the outstart. In case the poisonous nature of the food is established by feeding experiments the affected or dead animals may be examined by the usual methods for bacteria. It should be remembered, however, that there are cases in which no bacteria can be detected in the dead body, for the reason that they may be unable to multiply in the living body, although they may elaborate powerful poisons in the food itself. Death in such instances would be the result of a true intoxication. On the other hand, the poisonous organism may grow in the body and an infection proper may result, in which case the germ will be found distributed through the body.

The feeding experiments should be supplemented by injections, subcutaneous and intraperitoneal, of macerations of the food in sterile water. Eventually, aërobic and anaërobic cultures should be made with the poisonous food and the toxic organism should be isolated and its effects, in pure culture, studied upon susceptible animals. The presence of soluble poisonous products in such cultures may be demonstrated by filtration through porcelain.

Frederick G. Novy.

FOOT.—It is natural to compare the foot, as the distal member of the lower extremity, with the hand, the corresponding member of the upper; and by such a comparison we get most valuable aid to a comprehension of its structure. It has been said that the foot is merely a hand altered by the functions of support and locomotion which it has had to perform. While it is in general true that foot and hand are constructed upon a similar plan, it must be remembered that the differentiation commences far down in the animal series. The similarity between the anterior and posterior extremities of a quadruped, such as the horse for instance, disappears to a considerable extent when the anatomical structure is closely examined. Even in quadrupedal locomotion the posterior extremities are the ones most active in propelling the body, the anterior limbs being mainly for support and equipoise. The impression of the forefeet of an unshod horse is different from that of the hindfeet on this account. As the forelimbs come to be more used for the purposes of prehension and dexterity, the difference in structure becomes more marked. The higher apes were improperly called quadrumana, for no animal, speaking strictly, has four feet anatomically similar; still less has any animal four organs that can properly be called hands. The differences are various, according to the adaptation of the anterior and posterior members for the special activities of the animal. The bones of the carpus are never found to be the same as those of the tarsus, varying either in number or in the union of the various osseous elements. There is not, properly speaking, any opposability of the great toe in apes, as it cannot be carried around and placed at will against the various other toes; but it is set at a wider angle than the others, so that it can be used like the curve of a pincers or of a cramp-iron for grasping and climbing. The posterior extremities of apes are merely feet adapted for walking upon trees, the resemblances of the foot or "hind-hand" to a true hand being only skin deep (Huxley [1]).

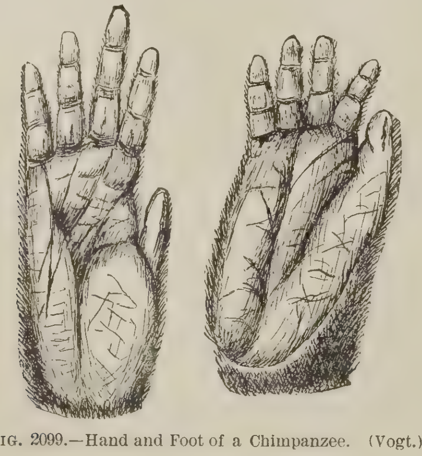


FIG. 2099.—Hand and Foot of a Chimpanzee. (Vogt.)

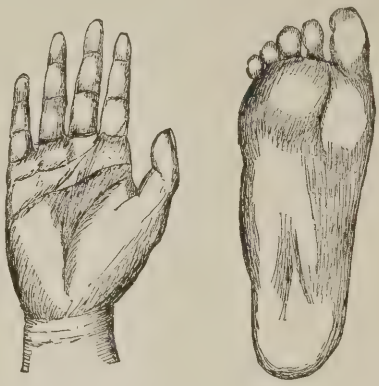


FIG. 2100.—Hand and Foot of Man. (Vogt.)

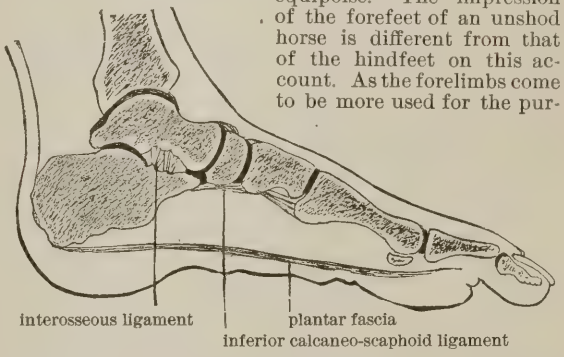


FIG. 2101.—The Antero-posterior Arch of the Foot. The bones shown are those cut by a longitudinal section through the axis of the great toe. The calcaneum forms the posterior branch of the arch; the scaphoid, internal cuneiform, the first metatarsal, the anterior branch; and the astragalus is at the summit. A sesamoid bone is seen under the head of the first metatarsal. In front are the phalanges of the great toe.

There seems from the structure of the human foot no reason to doubt that it has been developed from an organ adapted for the same use. Strong evidence of this is found in the fœtal condition of the foot, which approaches in many respects that of the anthropoid apes, there being less development of the heel, an arrangement of the joints which permits more inversion of the sole, and a difference in the corresponding length of the first and second metatarsal bones, indicating that the adult condition, in which the great toe is as long as, or longer than, the others, has been gradually acquired. Leboucq[2] determined the average proportion of the first metatarsal to the second to be in the child before birth as 1 is to 1.37; at fourteen years, as 1 is to 1.21; and in the adult as 1 is to 1.17.

Fig. 2099 shows the hand and the foot of the chimpanzee contrasted, while Fig. 2100 shows the same members in adult man. In the gorilla the resemblance to the human hand and foot is still greater. The feet of a child that has never walked show decided differences in power of using the toes, there being considerable grasp and the same imperfect opposability of the great toe as is seen in apes. The markings upon the sole show this to some extent.

The markings on the foot of a child that has never worn a shoe, nor stood alone upon its feet, resemble somewhat those of the palm of the hand, indicating considerable freedom of flexion and a certain amount of independent use of the great toe. They almost entirely disappear after the foot is used as a support. The power of the great toe may, however, be kept up if the feet are not confined, and many savage tribes use the foot for grasping. Among Australian savages this grasping power is of great assistance in climbing trees, and they habitually pick up a spear or similar object with the foot. Nubian horsemen are said to use the reins, and Chinese boatmen to pull an oar, by means of the great toe. Occasionally persons may be found who, either born without hands or, losing them early in life, have acquired the habit of using the foot for various acts ordinarily performed by the hands, and can thread a needle (as do the Hindoo tailors), use scissors, or even write, with the toes. The fact that walking in the erect position is learned only with difficulty shows that it is a late acquirement.

The main characteristics of the human foot are, therefore, those which adapt it for support and locomotion. For this purpose a most beautiful structural arrangement has been effected, combining great strength with peculiar elasticity and lightness. The bones are set in the form of a vault supported at the points connected by arches, two of these starting from the same point of the heel (the tuberosity of the calcaneum), and extending forward, one to the ball of the great toe (head of first metatarsal), the other to a corresponding point on the little toe. The third arch is transverse, connecting the anterior ends of the longitudinal ones.

The inner arch is formed by the calcaneum behind and the first, second, and third metatarsals, the cuneiform, and scaphoid bones in front, with the astragalus set at the vertex as a keystone (see Fig. 2101). The outer arch, which is much flatter, is formed by the calcaneum, cuboid, and two outer metatarsals which articulate with it. The transverse arch is formed behind by the three cuneiform bones and the cuboid (Fig. 2102), in front by the metatarsal bones. It should be noted that this arch becomes shallower and shallower as the toes are approached, until at last upon reaching the heads of the metatarsals the weight is borne fully upon them all. The imprint of a normal human foot, shows this clearly. The height of the arches forms the instep, a feature peculiar to man, and which varies considerably in different races, being generally higher in the Indo-European than in others. Arabs are said to boast that their insteps are so high that water will run under them without wetting the sole, and the Andalusian instep is famous. A popular saying has it that the foot of the negro is so flat that it makes a hole in the ground. A very amusing proof of this primitive condition of the negro foot may be noticed in Southern cities, where, during the heat of summer, it is customary to wet the pavements in the evening. It is not unusual to see barefooted negro boys, whose feet are so flat that atmospheric pressure makes them adhere slightly when applied to the wet and smooth pavement, in the same way that a boy's leather sucker adheres to a smooth stone, and it is a favorite pastime with such gifted individuals to walk the streets, producing a somewhat startling report every time the foot is withdrawn from the pavement. It is perhaps not without some reason that the height of the instep is considered a mark of pure blood, as it appears to be one of the signs of complete adaptation to the erect posture and to locomotion in that position.

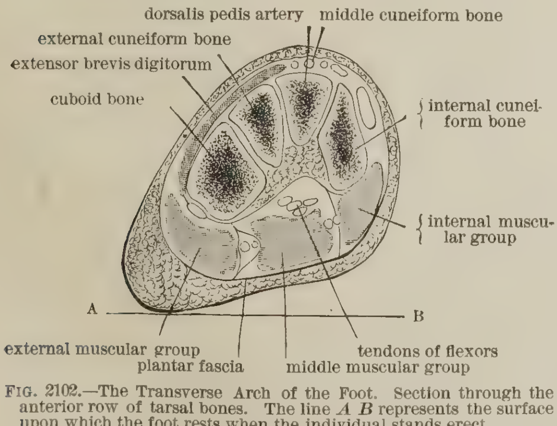


FIG. 2102.—The Transverse Arch of the Foot. Section through the anterior row of tarsal bones. The line *A B* represents the surface upon which the foot rests when the individual stands erect.

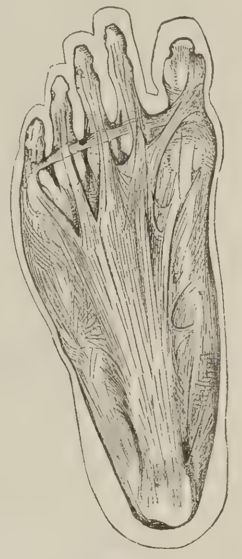


FIG. 2103.—Dissection of the Foot showing the Plantar Fascia. (Marshall.)

Man is the only animal that has the foot placed at right angles to the axis of the body, most mammalia not touching the ground with the calcaneum at all. The horse, for instance, literally walks upon the points of the toes, the hoof being comparable with the nails of the human foot, and the hock or "knee" being the tuberosity of the calcaneum. There appears to be some relation between this ascension of the calcaneum and the fleetness of the animal, as those which are the swiftest have the bones so arranged that they walk merely upon the tips. If support alone were needed there would be no necessity for the metatarsal bones and toes, as may be seen in those who have had them amputated. The anterior part of the arch is therefore for purposes of locomotion, and it may be noted that in running the heel is raised off the ground, and the anterior part only is used, the anatomical relation of the bones to the soil being similar to that which occurs ordinarily in the foot of the carnivora. The great swiftness and lightness of motion of a *première danseuse* is owing to her ability to dispense entirely with the posterior portion of the arch.

Owing to this difference of formation the anterior and posterior pillars of the longitudinal arches differ—the posterior, being for support, is short, thick, and strong, being of but one bone; the anterior, composed of several bones, is longer, so that the motion of raising the heel can be quickly performed. The length of the heel in the African race is merely apparent, and caused by the flattening of the arch rather than by a real projection. The number of bones in the anterior arch greatly aids in the distribution of the force, as any one may see who will take the trouble to note the difference in shock which occurs when alighting upon the heels rather than upon the balls of the toes.

This system is sustained by ligaments, tendons, and fascial bands in such a way as to form a most elastic and adjustable support. The longitudinal arches are held up by a strong sheet of connective tissue, one of the thickest aponeurotic structures in the body, the plantar fascia (Figs. 2101 and 2103), which is attached behind to the calcaneum, and in front divides into five slips, one for each toe, which pass forward and are mainly united to a band of transverse fibres which runs across the foot just behind the clefts of the toes.

This braces up the arches of the foot in the same way that a tension rod prevents the rafters of a roof from spreading. This arrangement is found only in the human foot, other animals having a plantar fascia movable like that of the hand, and usually with a special tensor like the palmaris longus of the arm. The little plantaris muscle of the human leg, which does not reach the foot, but unites with the tendo Achillis at the ankle, is the relic of such a structure.

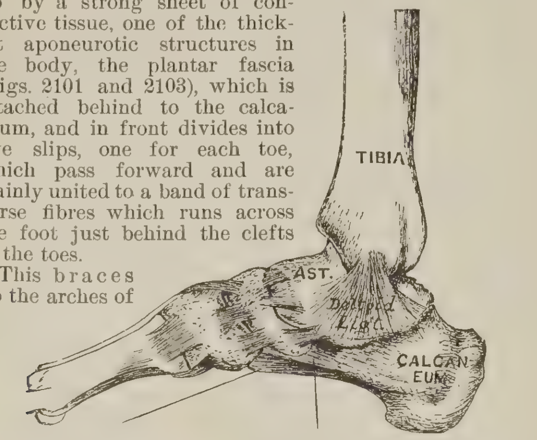


FIG. 2104.—The Ligaments on the Inner Side of the Right Foot.

When this fascia is very tense, it may draw the arch so closely together as to prevent the outside of the foot from touching the ground. This condition is not usually found in the normal foot, being the result of contracture of the fascia.

Besides this arrangement, the longitudinal arches are braced at the top by strong ligaments. A glance at Figs. 2101 and 2104 will show how necessary these are. The astragalus at its inner side overlaps the calcaneum, and would, in case of a lateral thrust, be shoved downward and inward into the space between that bone and the scaphoid were it not for the inferior calcaneo-scaphoid ligament, which passes from the projecting shelf of the calcaneum known as the sustentaculum tali, forward, under the astragalus, to the scaphoid. Its upper surface is lined with synovial membrane, and the cavity of the joint between the anterior part of the astragalus and the calcaneum is continued forward over it to the astragalo-scaphoid articulation. The tendon of the tibialis posticus passes forward under this ligament, and its fibres are united with it, strengthening it materially, and by its pull upon the scaphoid assisting the firmness of the joint exactly at that period of the step when the arch is most in danger; that is to say, when the heel is being raised and the weight thrown forward upon the scaphoid. If this ligament becomes weak or the muscle atrophied, the arch is depressed, the head of the astragalus descends below its proper level, and flat foot, or valgus, results. This is usually associated with arthritis, and is a very painful affection, differing much from the congenital form of the defect. It is found especially among those who stand for long periods of time.

On the outer side of the foot the arch is trussed up by means of a strong band called the long plantar ligament (Fig. 2104), passing from the tuberosity of the calcaneum forward to the base of the second, third, and fourth metatarsals.

To produce the transverse vaulting, certain short and oblique ligamentous bands are used, radiating from the scaphoid, the cuboid, and the external cuneiform bones, and these are assisted in a marked degree by the action of the muscles.

Fig. 2105 shows that the tendons of the peroneus longus and of the flexor longus digitorum are so arranged that they pull obliquely upon the bones of the foot, crowding them together and consolidating them transversely. Duchenne[3] was of the opinion that flat foot is frequently associated with an insufficiency in the peroneus longus. The members of the inner arch are decidedly more movable than those of the outer, which recalls the fact that it is only the outer part that is used for support among anthropoids.

The various interosseous ligaments assist considerably to keep the bones in place. The strongest of them is the one between the astragalus and the calcaneum (Fig. 2101), separating the articular surface into two distinct portions. It lies within a canal formed by grooves upon either bone, and known as the canalis tarsi, surrounded in that situation with fat.

The joints of the foot are adapted to the arch-like form above described. An inspection of Fig. 2101 will show that there is an approximation in these joints to arcs of circles, the larger arcs being in the posterior part of the arch, the smaller and more numerous forward. A study of the cancellated tissue of the bones shows that these arcs are continued to some extent by strengthening bars within the bone, showing that conditions of stress have occasioned this arrangement. The movements are generally those of rotation and not purely gliding (Bradley[4]). A uniformity of distribution of pressure is thus obtained. The ligaments which unite the different bones are of two classes: those which are special, surrounding and supporting particular joints; and those which are general, mainly employed in bracing and sustaining the arches of the foot. To the first class belong the capsular ligaments which are found at every joint, and are strengthened more or less by special bands, which receive names from the bones which they unite. The principal ligaments of the second class have already been mentioned. The movements are of two classes, one of which is a simple flexion and extension, mainly expressed in the joint between the astragalus and the leg bones (see *Ankle Joint*), and in the various metatarsal and phalangeal joints; the second a movement of inversion and eversion of the sole, sometimes called, rather inaccurately, adduction and abduction, or supination and pronation, and which takes place in the astragalo-calcanean joints. As already mentioned, the joint between the astragalus and the calcaneum is double, with two synovial sacs, the anterior being continuous with the astragalo-scaphoid articulation. The joint has been carefully studied by Miss Clark,[5] who made many measurements of it, both in fœtal and adult subjects. The facets on the astragalus are concave, and the axis of motion is a line extending from the insertion of the dorsal ligament binding the astragalus to the scaphoid through the head of the astragalus and the body of

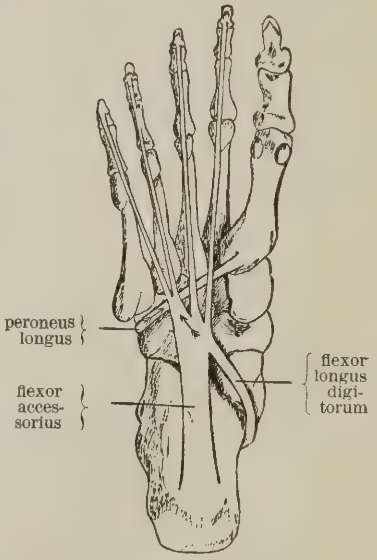


FIG. 2105.—Diagram of the Action of Some of the Principal Tendons which Consolidate the Transverse Arch of the Foot.

the calcaneum obliquely downward and backward to about the point where the middle band of the external lateral ligament is inserted. The movements which take place are really a nearly simple flexion and extension about this oblique axis, the former turning the sole inward (supination), the latter slightly outward (pronation). The arrangement of the axis of motion with reference to the axis of the astragalus is different in the fœtus, resembling that of anthropoids. The whole bone is quite differently shaped as regards the inclination of its articular surfaces, they being adapted to the fœtal position, which is that of dorsal flexion and inversion of the foot. The head of the astragalus is so directed as to make the axis of the bone more nearly coincide with that of the motion of the joint. Inversion is therefore easier and more complete. The shape of the articular facet on the head of the astragalus is also different, its greatest diameter being less oblique than in adults. In the ape's foot inversion of the sole is necessary for climbing, and among Australian savages it is similarly used. This movement is undoubtedly very useful in correcting slight disturbances of equilibrium when standing erect. The direction of the facets in the adult is such that when the posterior part of the calcaneum slips forward and downward the anterior facet moves backward and upward, carrying the distal end of the bone slightly inward. For this reason inversion is always accompanied by a turning in of the toes, and eversion by turning them out. A further degree of this movement of the toes is found in the astragalo-scaphoid, a shallow ball-and-socket joint, the round head of the astragalus being received into the posterior hollow facet on the scaphoid. It is this joint that gives to the foot the great freedom of movement that is enjoyed by dancers. A comparison of these joints with those of the wrist will show at once that there is no real homology possible between them. Dislocation may occur here, the interosseous ligament being torn and the malleoli usually fractured at the same time.

The peculiar condition of the fœtal foot, with reference to this joint, is probably the primary cause of the different varieties of club foot. The most common form, or varus, is the persistence of the fœtal condition of inversion of the sole. The articular surfaces between the calcaneum and the cuboid are saddle-shaped, and have a triangular outline. The movements allowed here are like those of the astragalo-scaphoid joint, but less in extent. The whole articular line between the astragalus and calcaneum behind, and the scaphoid and cuboid in front, is known as the medio-tarsal joint, sometimes called Chopart's joint by surgeons because of the operation frequently performed there. The movements of the other joints of the foot are similar to the corresponding ones of the hand. The great toe is the only one that lies perfectly extended, the others being more or less flexed. Together they give elasticity to the last act of walking, when the weight is thrown forward upon the other foot.

In considering the surgical anatomy of the articulations of the foot, it is necessary to note that the bones fall naturally into three grand divisions of tarsus, metatarsus, and phalanges, and that the tarsal bones are divisible into an anterior group, composed of the three cuneiform bones, the cuboid, and the scaphoid, and a posterior group, the calcaneum and the astragalus. The astragalus may itself be considered separately, as it lies more superiorly and with a horizontally directed joint surface. There are, therefore, the following lines in which disarticulation can be effected: First, between the different phalangeal and metatarso-phalangeal joints; second, the tarso-metatarsal line; third, the medio-tarsal line; fourth, the sub-astragaloid line; and, lastly, the cruro-tarsal line, by which the entire foot may be removed. The phalangeal joints are easily found by remembering that it is always the proximal phalanx that forms the prominence in flexion, and that the opening must therefore be somewhat forward from that. The same may be said for the metacarpo-phalangeal joints, the general line of which lies about three-fourths of an inch behind the skin fold connecting the toes. The exposed condition of this part of the foot, as well as its distance from the heart, renders it liable to some injuries, such as chilblains, and senile gangrene. The tarso-metatarsal line is used for the operations of Hey and Lisfranc, neither of which is frequently performed, as disease is very rarely confined to the metatarsal bones. Hyrtl's[7] rule for finding the joint on the inner side is that it lies exactly at the half-length of the sole. It is also about an inch and a half in front of the tubercle of the scaphoid, which may be easily felt on the inner side of the foot in front of the point of the internal malleolus. A slight eminence may usually be felt on the posterior extremity of the first metatarsal by holding the foot steady, pressing firmly on the skin, and thus following back the smooth internal surface of the shaft of the bone. On the outer side the line cannot be missed, as it lies directly behind the prominent tubercle at the base of the fifth metatarsal. The base of the second metatarsal bone is received between the inner and outer cuneiform bones, the middle cuneiform being correspondingly lessened in length. This adds considerable firmness to the arches, but makes the line quite irregular and is an obstacle to the speedy performance of the operation. Disarticulation is now usually practised; but Hey sawed through the metatarsal, leaving the base in place. Tillaux[8] remarks that although the irregularity of the line varies, the joint of the second cuneiform is always at a definite interval behind that of the first—about a centimetre. The interosseous ligaments are strong, and are the principal obstacle to the knife.

In the medio-tarsal line the operation known as Chopart's is performed. The line is not very difficult to find as it lies on the inner side just behind the tubercle of the scaphoid, and externally just in front of the prominent edge of the head of the calcaneum. This latter is midway between the external malleolus and the tubercle on the metatarsal bone of the little toe. There is no irregularity in the line, it being composed of two curves, one between the scaphoid and astragalus, convex forward, the other between the calcaneum and cuboid, convex backward. The principal obstacle to the knife is the calcaneo-cuboid or Y-ligament, which is strong and thick, radiating, as mentioned before, from the calcaneum to be inserted by two slips into the cuboid and the scaphoid. The calcaneo-scaphoid ligament which, it will be remembered, ties the vertex of the arch, is also divided in this operation. In old subjects it is occasionally found to be ossified.

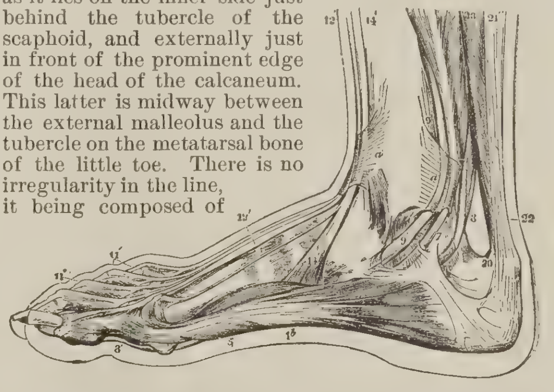


FIG. 2106.—View of the Muscles and Tendons on the Inner Side of the Right Foot. *a*, *a*, Annular ligaments; 1*b*, abductor pollicis; 7', tendon of flexor longus digitorum; 8', tendon of flexor longus hallucis; 9', tendon of tibialis posticus; 11', tendons of extensor longus digitorum; 12', tendon of extensor longus hallucis; 14', tendon of tibialis anticus; 22, tendo Achillis. (Marshall.)

Disarticulation under the astragalus is not often resorted to. As there are no muscles attached to that bone, it can be of little service even if left in place.

The muscles of the foot are divided by their position into intrinsic and extrinsic; those which have their origin above belonging to the latter class. The division is topographical rather than scientific, for there is no doubt that many of the muscles now found in the foot primarily had an origin higher up, and have become displaced in the course of phylogenetic development.[9] The extrinsic muscles are the most active agents, the intrinsic mostly aiding and supplementing them. They fall quite naturally into four groups—an anterior, supplied by the anterior tibial nerve and composed of the tibialis anticus, extensor proprius hallucis, extensor longus digitorum, and peroneus tertius; a lateral, supplied by the peroneal nerve and composed of the peroneus longus and brevis; and two posterior, the superficial supplied by the internal popliteal nerve and composed of the muscles inserted into the tendo Achillis (gastrocnemius, soleus, plantaris), and the deep, supplied by the posterior tibial nerve and composed of the tibialis posticus, flexor longus digitorum, and flexor longus pollicis. All of these pass over two joints, the ankle joint or astragalo-crural and the astragalo-calcaneal, and therefore occasion motion at both, but in very varying degrees.

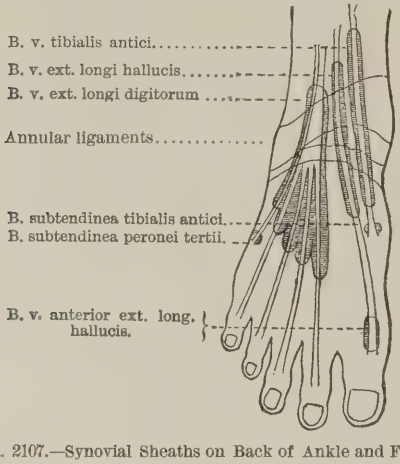

B. v. tibialis antici
B. v. ext. longi hallucis
B. v. ext. longi digitorum
Annular ligaments
B. subtendinea tibialis antici
B. subtendinea peronei tertii
B. v. anterior ext. long. hallucis.

FIG. 2107.—Synovial Sheaths on Back of Ankle and Foot.

The tendons of the anterior group may be seen in Figs. 2106, 2107, and 2113, and passing down over the ankle, where they are held in position by thickened bands of fascia known as the annular ligaments. There are two of these, an upper one (ligamentum transversum cruris), not shown in the figures, extending across the lower part of the leg from fibula to tibia, and a lower one (ligamentum cruciatum), in the form of a ≺, placed thus on its side (the shape best shown in Fig. 2107), the main stem being a strong loop-like band which lies on the outer portion of the ankle, springing from the fore part of the calcaneum in the deep fossa between that bone and the astragalus known as the sinus tarsi. It completely surrounds the tendons of the peroneus tertius and extensor longus digitorum (see Fig. 2108, *a*). This band was first described by Retzius, who gave it the name of ligamentum fundiforme tarsi. It is of considerable strength, and gives a new direction to the tendons, so that they pull more exactly in the line of the toes (see Fig. 2113), thus forming a sort of trochlea like that which the superior oblique muscle of the eye has. According to Hyrtl it usually becomes cartilaginous in old people. By a sprain the tendons may be torn from this connection, and will then be seen to take a much more direct line to the toes. From this band the two branches of the ligamentum cruciatum diverge, passing over the tendons of the extensor proprius hallucis and the tibialis anticus. The tendons which pass down over the dorsum are provided with certain synovial sheaths which are shown in Fig. 2107. The tendon of the tibialis anticus (14′ in Fig. 2106) is the largest and strongest, and may be easily made out whenever the foot is flexed and the sole at the same time bent inward. As it is inserted into the internal cuneiform and base of the first metatarsal, it necessarily flexes the foot and inverts the sole. It will be seen that the attitude is much like that of varus, and in fact this muscle is one of the most active agents in that deformity. In dividing the tendon care must be taken not to open the astragalo-calcaneal joint.

The tendon of the extensor proprius hallucis comes next (see Fig. 2113). It is also very large and strong and is the most prominent cord in front during flexion of the foot. On this account it is the first to suffer from any tightness of the covering about the ankle. It is inserted into the last phalanx of the great toe, which it strongly extends in the last act of walking just as the foot is about to leave the ground. Continuing its action, it flexes the foot on the leg and assists the tibialis anticus to invert the sole. It is more firmly enclosed by the cruciate ligament than the tibialis anticus, and its pull upon that band raises the arch slightly so that its impression is fainter.

The extensor longus digitorum sends tendons to the four outer toes which unite with those of the extensor brevis and are inserted into the second and third phalanges. Closely associated with this muscle is the peroneus tertius, a thin muscular slip which sends a tendon to the metatarsal bone of the little toe. It hardly deserves a separate name.

The action of the extensors upon the toes is reinforced by the lumbricales from the sole of the foot. These muscles arise from the *flexor* tendons and pass around the phalanges to be inserted into a triangular aponeurosis, which is common to the extensor muscles. In walking, therefore, as the flexors assist in raising the foot they give a firm basis for the pull of the lumbricales, so that in the final act of rolling the weight forward upon the toes they can assist the extensors. It should be remembered that the division of the muscles into flexors and extensors is not, in so far as it implies an antagonistic condition, entirely correct.[10] Those muscles which extend the toes also flex the foot, and *vice versa*. There is no loss of muscular force, as there would be did one set pull directly against the other.

The extensor brevis (see 10, Fig. 2108), though an intrinsic muscle, should be mentioned here, as it belongs morphologically to the same group. It was originally a leg muscle, and has gradually slipped down, all stages of its descent being seen in different animals.[9] It arises from the forepart of the upper and outer surfaces of the calcaneum, and presents, on the outer side of the foot, a considerable muscular belly, which contributes to the modelling of that part of the foot, and is soft and pulpy to the touch. This should be remembered in examining the ankle for suspected joint disease, or after a sprain. When struck lightly it will quiver, and this movement has been mistaken for fluctuation, and the muscle has been incised in mistake for an abscess. The tendon which goes to the great toe is usually somewhat separated from the others, and that part of the muscle has been described separately as an extensor brevis hallucis.

The extensor brevis varies considerably, especially with regard to the amount of division of the various muscular bellies of which it is composed, and there is occasionally seen a tendency for it to become merged with the dorsal interossei, elements of an entirely different origin.

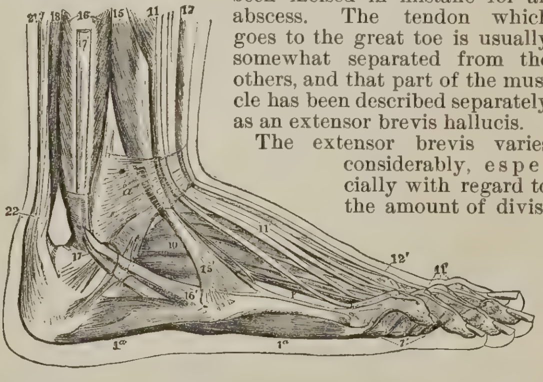


FIG. 2108.—View of the Muscles and Tendons on the Outer Side of the Right Foot. *a*, Ligamentum fundiforme; 1*a*, abductor minimi digiti; 7′, insertion of the tendons of the flexor longus digitorum; 10, extensor brevis digitorum; 11′, tendons of the extensor longus digitorum; 12′, tendon of the extensor longus hallucis; 15, tendon of the peroneus tertius; 16′, tendon of the peroneus brevis; 17′, tendon of the peroneus longus; 22, tendo Achillis. (Marshall.)

The peroneus longus and brevis (16′ and 17′, Fig. 2108) were primitively upon the front of the fibula, but their tendons have been shifted behind the outer malleolus for adaptation to climbing. They are here held by a strong sheet of fascia (retinaculum superius), and are similarly sheathed (retinaculum inferius) where they lie in a groove on the outer side of the calcaneum. Notwithstanding this secure attachment the tendons are more frequently displaced than any others in the body. Leaving the groove they diverge from each other, the brevis being inserted into the tubercle of the fifth metatarsal, and continued by a thin tendon as far as the toe, the longus passing across under the arch of the foot in the groove on the inferior surface of the cuboid, and being inserted into the tubercle of the first metatarsal bone (see Fig. 2105). They strongly evert the sole, producing a condition like that of valgus.

The peroneus tertius, the extensor longus digitorum, and the extensor brevis digitorum, were originally parts of the same muscle sheet which belonged to the back of the foot and front of the leg. The twisting over of the foot into its position with the plantar surface downward has caused them to appear in their present situation. Extra peroneal muscles are not infrequent, and in one dissection performed by the author a set of five were found.

The main body of the flexor tendons passes down on the inner side of the ankle. Fig. 2109 shows, in a diagrammatic form, how they are arranged, and their tendons are seen in Fig. 2106. Besides these there should be mentioned those muscles (the soleus and gastrocnemius) which are inserted through the tendo Achillis upon the calcaneum. Duchenne's experiments[3] in the faradization of muscles led him to the conclusion that these latter act as extensors and adductors of the foot, while the peroneus longus is an extensor and abductor. In order to get a powerful and equal extension of the foot both of these act together, and this may be increased by a simultaneous contraction of the flexor longus digitorum and flexor longus pollicis. He supposes that the reason for the peculiar action of the tendo Achillis in causing adduction is occasioned by the arrangement of the plantar ligaments. The strongest bands lie on the outer side of the foot, and this determines a deviation of the line of action in that direction.

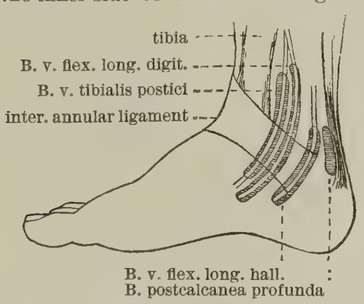


FIG. 2109.—Synovial Sheaths of Inner Side of Foot.

It was formerly supposed that the severing of the tendo Achillis was a necessarily fatal injury. Hippocrates was firmly of this opinion, and one of the names given to the tendon is chorda magna Hippocratis. It was undoubtedly a serious matter when the wound was an open one and proper drainage not secured; but with the modern resources of surgery it is often safely divided for the relief of club foot. For about an inch and a half above its lower end it is free from muscle fibres, and narrows slightly, and it may be cut there, care being taken to avoid the vessels and nerves at its inner side, and the bursa which exists just above its insertion (see Fig. 2109). Rupture of the tendon has occurred from violent muscular action in jumping.

The tendons of the tibialis posticus, the flexor longus digitorum, and the flexor longus hallucis pass down behind the internal malleolus in a special compartment, confined by a strong band of fascia known as the internal annular ligament, which passes from the malleolus to the calcaneum, enclosing not only the tendons but the vessels and nerves which accompany them. They have special synovial sheaths (Fig. 2109), and are so arranged that the tendon of the flexor longus hallucis is nearest the tendo Achillis, that of the flexor longus digitorum next, and that of the tibialis anticus nearest the malleolus, the tendon of the digital flexor twisting around it from without inward, and then passing downward, forward, and outward under the sole. Were it not for this the tendon of the tibialis posticus would be likely to slip from under the malleolus or the sustentaculum tali as it passes forward to be inserted into the tubercle of the scaphoid, and by a tendinous expansion into all the bones at the upper part of the vault except the astragalus. It strongly inverts the sole and raises the head of the first metatarsal. Spigelius called it musculus nauticus, because it was necessarily used by sailors in climbing masts.

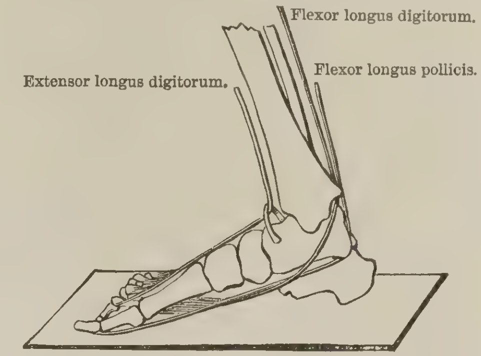
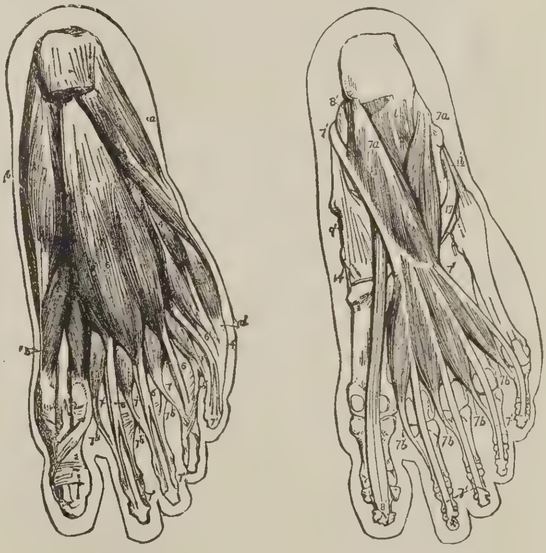


FIG. 2110.—Diagram Showing the Manner in which the Flexor and Extensor Tendons are Reflected around the Ankle. (Langer.[13])

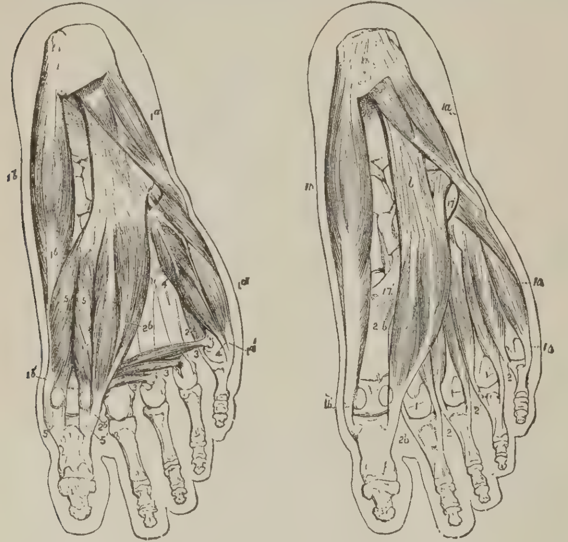
The flexor longus digitorum and the flexor longus hallucis are arranged somewhat like the flexor profundus digitorum and the flexor longus pollicis of the hand, as they have an arrangement of tendons which pass in a similar way through those of the flexores breves to be inserted into the terminal phalanges of the toes. But they are very differently related in the sole, for they not only decussate and unite there, but the flexor longus digitorum receives a reinforcement from an accessory head, the flexor accessorius, or caro quadrati Sylvii, arising from the tuberosity of the calcaneum, and inserted at



First Layer. Second Layer.

FIG. 2111.—The Muscles of the Sole of the Foot. 1*a*, Abductor minimi digiti; 1*b*, abductor hallucis; 6, flexor brevis digitorum; 7′, tendon of flexor longus digitorum; 7*a*, its plantar head, or flexor accessorius; 7*b*, 7*b*, lumbricales; 8′, tendon of flexor longus hallucis; 17, tendon of peroneus longus; 9′, insertion of tibialis posticus.

the decussation. The crossing in the sole is such that in the greater number of cases the tendon of the flexor hallucis sends to the decussation a lateral twig, which again divides in slips for the second and third toes, uniting with the tendons of the flexor digitorum. The slip to the third toe may be wanting, but sometimes one is sent to the fourth. This arrangement recalls the musculature of the ape's foot, where the hallucis tendon supplies the third and fourth toes, and sometimes the second, while the digital tendon is mainly confined to the second and fifth, or to the second only, the great toe receiving only a slender tendon which quite fails in the orang. The unusual development of the hallucis in man appears to be connected with the use of the great toe for preserving the equilibrium in the erect position.



Third Layer. Fourth Layer.

FIG. 2112.—The Deep Muscles of the Sole. 4, 4, Flexor brevis minimi digiti; 5, 5, flexor brevis hallucis; 2*b*, adductor pollicis, with its detached heads; 3, 3, 3, also called the transversus pedis; 1, 1, 1, dorsal interossei; 2, 2, 2, plantar interossei.

The plantar head mainly reinforces the tendons for the third and fourth toes.[11] The whole apparatus appears to indicate that the original plan was for a flexor fibularis (flexor longus hallucis) and a flexor tibialis (flexor digitorum), and that the flexor accessorius originally belonged to the latter muscle, but afterward lost its insertion upon the fibula. Variations are found which tend to confirm this.

It will be noticed that the most direct pull appears to be toward the second and third toes; the tendons there are supplied, not only from the common flexor, but also from the tendon of the hallucis. This would appear to show that the original axis of the foot, or line on which it rolls, is not through the great toe, as usually stated, but through the second and third toes, and would bear out the experiments of Beely,[12] who found that in a cast taken from the impression made by his foot while standing upon a layer of soft plaster, the heads of the second and third metatarsals made a deeper impression than any other portion of the anterior part of the foot.

The action of the flexor is to bend the toes and contribute to the stability of the foot in standing. After bending the toes they also flex the medio-tarsal joint.

So it follows that these muscles all co-operate in lifting the heel from the ground and flexing the foot, and that, as this is done, the toes are strongly flexed and pressed against the ground like an elastic spring (see Fig. 2110).

They are often divided in orthopædic operations, usually at the malleolus, as it should be remembered that the posterior tibial artery lies near the flexor longus digitorum, being exactly in the middle of the space between the posterior margin of the internal malleolus and the internal border of the tendo Achillis. The nerve is in the same sheath with the artery and behind it.

The intrinsic muscles of the sole, which are quite numerous, are shown on Figs. 2111 and 2112. They are arranged in three groups, separated from each other by appropriate layers of fascia, as shown in Fig. 2102. The external group is composed of muscles relating to the little toe, the flexor brevis and abductor minimi digiti; the inner is a similar group relating to the great toe, the flexor brevis and abductor hallucis; while the middle set is related to the muscles which come down from the calf, the flexor accessorius and the lumbricales, together with the flexor brevis digitorum and adductor pollicis. Deep under all these lie the interossei. The muscle sometimes described as transversus pedis is not entitled to a separate description, as it is clearly shown by the evidence of embryology to be a portion of the adductor pollicis.

These muscles are of special use in supplementing the action of the ligaments in supporting the arches, giving an elastic support variable according to the nature and direction of the strain. The interossei are in two groups, the plantar and the dorsal, the latter not being prominent on the sole. All originally developed upon the sole, the dorsal gradually passing up between the metatarsal bones during fœtal life. Cunningham[14] thinks that the primitive typical arrangement of the intrinsic plantar muscles is the same as that of the hand, viz.: that there is a plantar layer of adductors of the toes represented by the

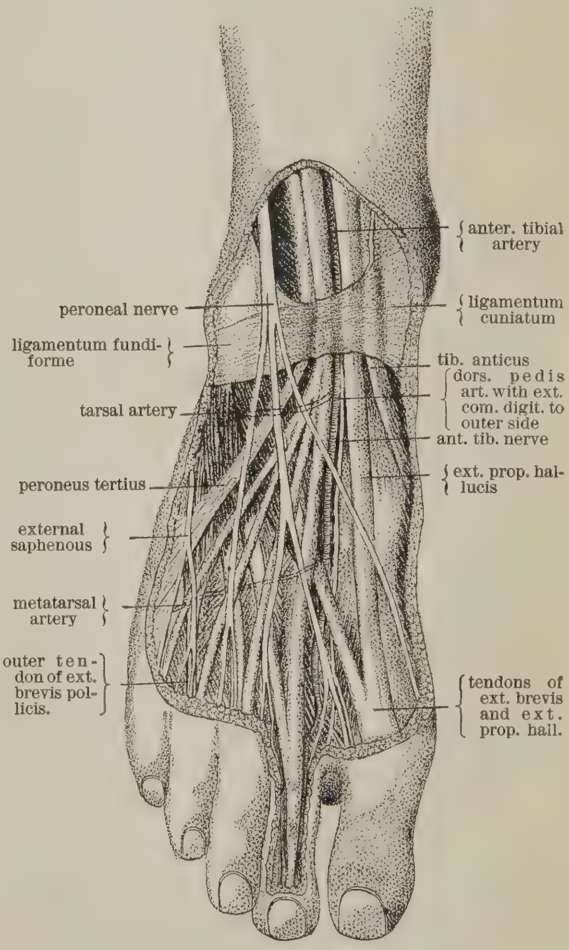


FIG. 2113.—A Dissection Showing the Deeper Structures on the Dorsum of the Foot.

adductor hallucis and its detached head, the transversus pedis, and the three plantar interossei; an intermediate layer of flexores breves, composed of the flexor brevis minimi digiti and the flexor brevis hallucis; and a dorsal layer of abductors of the toes represented by the abductor hallucis, the abductor minimi digiti, and the dorsal interossei. The layers have lost their relative planes in the foot partly because of the arched condition, and partly by suppression of the flexores breves for the second, third, and fourth toes.

The nerves of the foot give us important evidence with regard to the value and previous history of the muscles. Those derived from the lumbar plexus do not have any motor functions, but supply sensation to the integument of the inner side (long saphenous nerve). The sacral plexus gives sensations to the remaining portions, viz., by the external saphenous on the inner side, the musculo-cutaneous over the dorsum, and the plantar nerves on the sole, the internal plantar supplying the first three toes and half of the fourth, the external supplying the other half of the fourth and the fifth. The nerves of the dorsum are shown in Figs. 2113 and 2115; those of the sole in Fig. 2114.

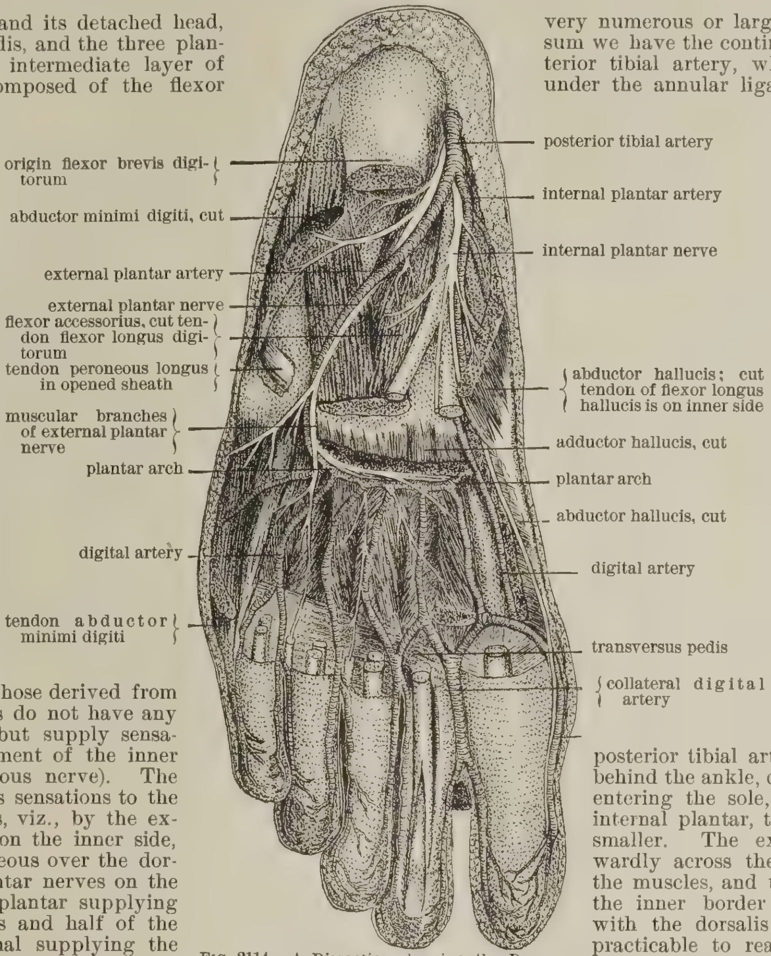

origin flexor brevis digitorum
abductor minimi digiti, cut
external plantar artery
external plantar nerve
flexor accessorius, cut tendon flexor longus digitorum
tendon peroneous longus in opened sheath
muscular branches of external plantar nerve
plantar arch
digital artery
tendon abductor minimi digiti
posterior tibial artery
internal plantar artery
internal plantar nerve
abductor hallucis; cut tendon of flexor longus hallucis is on inner side
adductor hallucis, cut
plantar arch
abductor hallucis, cut
digital artery
transversus pedis
collateral digital artery

FIG. 2114.—A Dissection showing the Deeper Structures on the Sole of the Foot.

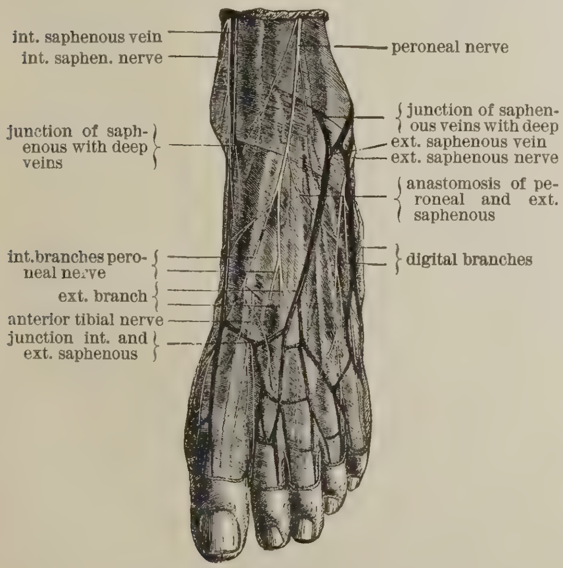

int. saphenous vein
int. saphen. nerve
junction of saphenous with deep veins
int. branches peroneal nerve
ext. branch
anterior tibial nerve
junction int. and ext. saphenous
peroneal nerve
junction of saphenous veins with deep
ext. saphenous vein
ext. saphenous nerve
anastomosis of peroneal and ext. saphenous
digital branches

FIG. 2115.—The Superficial Veins and Nerves of the Dorsum of the Foot.

The vessels of the foot (see the same figures) are not very numerous or large. Upon the dorsum we have the continuation of the anterior tibial artery, which, as it passes under the annular ligament, changes its name to dorsalis pedis. It is accompanied by two veins, and passes forward to anastomose, at the space between the first and second toes, with the external plantar. It is believed to correspond to the radial artery of the hand, and it will be seen that the twisting over of the dorsal surface has given it a less devious course. It is easily secured in the upper part of its course, where it lies quite superficially and just external to the tendon of the extensor longus hallucis. Aneurism has occurred in it as a sequel to a sprain. The posterior tibial artery, coming down behind the ankle, divides, just before entering the sole, into external and internal plantar, the latter being the smaller. The external runs outwardly across the foot, deep under the muscles, and then turns again to the inner border and anastomoses with the dorsalis pedis. It is not practicable to reach these for ligature in the sole, except by resection of the metatarsal bones.

The superficial veins are found mainly upon the dorsum. A reference to Fig. 2115 will show that the internal and external saphenous veins coming down from above anastomose with each other across the metatarsal bones, forming an arch with the convexity toward the toes. Tight boot-lacings may so compress these veins as to produce a stasis, with pain and swelling. Veins of any considerable size are wanting upon the sole.

The integument of the sole of the foot is intimately united with the layer of subcutaneous fat, which is here not loose and movable, but shut into distinct compartments by septa of connective tissue. This forms a very compact and elastic cushion for supporting the weight of the body.

Smallness of these members has been during all modern times considered a mark of beauty. There seems to be no

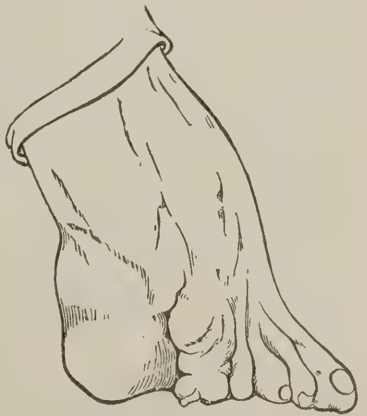


FIG. 2116.—Deformed Foot of a Chinese Lady of Rank. (Langer.)

good reason for this, except that it indicates a general delicacy of construction of the body and can hardly be associated with habits of labor. Structurally a small foot would seem to be an ineffective organ. The Chinese women of rank are, as is well known, so treated in infancy that the foot has no opportunity to grow, and soon becomes misshapen, as shown in Fig. 2116, reduced from a photograph by Welcker. The operation commences usually in the second year of the child's life, and consists in turning the toes under the sole and confining them there by bandaging. The procedure is said to be quite painful, and sometimes fatal to delicate children. If the parents belong to a class in which labor will be required of the child, nothing further is done, and the foot, though deformed, can still be used for walking. If they are wealthy, the deformity is carried further by so bandaging the foot that the great toe approaches the heel as nearly as possible. As to the motive for this strange custom, it seems probable that it originated in an attempt to increase the value of the female as an object of sexual appetite. As the woman can move about but little, a greater deposit of fat is found on the mons veneris, and the nymphæ are thickened. Besides this, it is said these deformed feet are kept carefully covered, because they resemble in appearance the vulva. Only prostitutes display their feet, and for the purpose of enticing customers (Stricker[15]). Fig. 2117 shows the skeleton of such a malformation. *Frank Baker.*

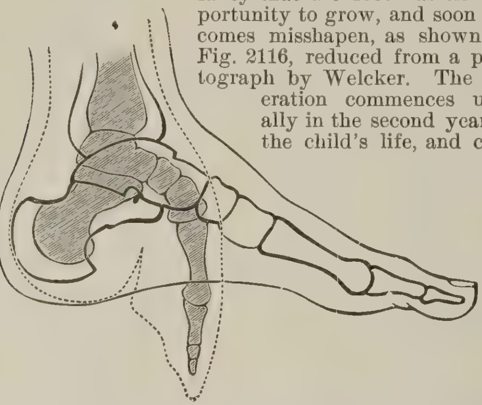


FIG. 2117.—Section of Natural Foot with the Bones, and a Corresponding Section of a Chinese Deformed Foot. The outline of the latter is dotted, and the bones are shaded. (Flower.)

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[1] Huxley, T. H.: Evidence as to Man's Place in Nature.

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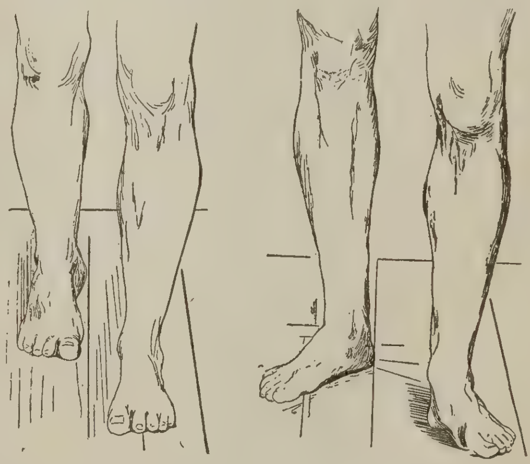
FOOT-AND-MOUTH DISEASE. See *Hoof-and-Mouth-Disease.*

FOOT, DISABILITIES OF.—I. THE WEAK FOOT. (Synonyms: Splay foot; flat foot.) The most common and by far the most important of the disabilities of the foot is the so-called flat foot. This affection, although so common, is still very imperfectly understood and in order to make its etiology, and the principles that should govern its treatment, clear, one must contrast the appearance and the functional ability of such a disabled foot with those of the normal member.

The foot is supported by ligaments, by the muscles, and by the strong plantar fascia that covers in the sole. When it is in active use it is in great part supported by the muscles, but when it serves as a passive support, as in standing, the ligaments bear the greater part of the strain, and its normal elasticity allows the bearing surface to expand slightly as the arches are slightly depressed. It must not be understood, however, that the longitudinal arch is simply flattened by direct pressure and by elongation of elastic ligaments and fascia. Ligaments and fascia are not elastic and they are not, in the normal foot, overstretched. The change in contour is the effect of normal motion in the joints of the foot, by which it is placed in the most favorable attitude for weight bearing without muscular exertion.

Of the changes of contour that distinguish the foot used as a passive support from the one that bears no weight, the most significant is the obliteration of the outward curve of its internal border. This change is due to the fact that the astragalus, bearing the leg, rotates inward and downward on the os calcis until it is checked by the resistance of the ligaments and by the interlocking of the bones. The head of the astragalus thus becomes slightly prominent; the inner border of the foot is depressed, and an attitude is attained in which the weight of the body may be supported with but slight muscular exertion. This position of the foot is one of a series of similar changes in the relation of the bones of the lower extremity, which are instinctively assumed when the limb is placed in the so-called attitude of rest.

The second function of the foot is as a lever to raise and to propel the body. The calf muscles supply the power and the heads of the metatarsal bones serve as the fulcrum on which the weight is lifted. When the foot is used as a lever it should be held in such relation to the leg that the line of weight, passing downward through the centre of the knee and ankle joints, is continued over the second toe or practically the centre of the foot. As the body is lifted over the fulcrum, the fore foot is turned inward in its relation to the leg or, more properly speaking, the leg is turned outward, because the inner side of the fulcrum, formed by the first metatarsal bone, is longer than its outer side. Thus the strain is directed toward the outer and stronger side of the foot (Fig. 2118, *A*).



A. *B.*

FIG. 2118.—*A*, The Proper Attitude in Activity, Illustrating the Adduction of the Fore Foot. *B*, The Improper Attitude of Outward Rotation of the Feet.

In the proper walk, which is the best illustration of the leverage function, the feet should be held practically parallel to one another, so that the line of strain may fall through the centre of the foot. As one foot is advanced it first bears weight momentarily on the heel, then upon its outer border; the heel is then raised and the body is lifted over the toes, the great toe giving the final impulse, so that if the walker is looked at from behind, he appears to be in-toeing at the termination of each step. Thus, during the walk, there is an alternation of postures, and the foot, under muscular control, assumes the attitudes most opposed to that of passive support.

The alternation of postures and the leverage action of the foot are by no means necessary to simple progression; for example, both feet might be fixed in plaster bandages yet walking would be possible just as it is possible on two wooden legs. Indeed an approximation to such a manner of walking is often seen, in which the passive attitude persists, leverage and its attendant motions being absent. Such a walk is necessarily jarring and ungraceful, and if it is not the result of weakness and deformity it predisposes to them because of the disuse of the proper function of the foot.

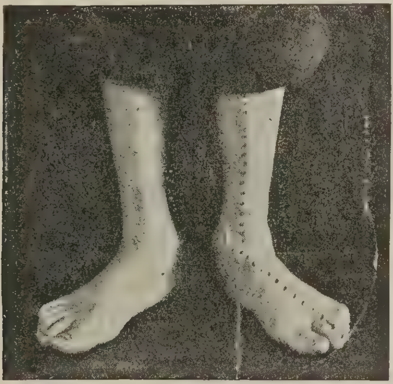


FIG. 2119.—Typical Weak Foot of Moderate Degree, Illustrating the Component Elements of Abduction and Depression of the Arch.

One of the most common causes of interference with the leverage function is the custom of turning the feet outward. Outward rotation of the feet is normal in the passive attitude of weight bearing, because it locks the joints and throws the strain upon the ligaments to relieve the muscles (Fig. 2118). On this very account it is the improper attitude for activity because the strain falls upon the inner border of the foot or to the inner side of the fulcrum, making the proper exercise of muscular power, and alternation of postures, impossible. Thus it will appear that a persistence of the passive attitude, or an approximation to it, is abnormal when the foot is in active use.

The persistence of an improper posture may be simply a habit, but it is evident that if an individual were overweighted by a heavy burden he could not walk with an elastic step, nor could he, if his muscular power were insufficient for normal activity, nor if the structure of the foot were weak, nor if active movements caused pain. In any one of these instances the passive attitude would be assumed habitually and the foot would approximate in appearance, to a greater or less degree, the so-called flat foot which is merely an abnormal persistence, and an exaggeration of, the attitude of rest.

If one contrasts the appearance of the foot in activity, under the control of, and supported by, the muscles, with one that is inactively supporting weight, he will appreciate the distinction between activity (strength) and passivity (weakness). If then the foot habitually assumes the passive attitude it may be properly called a weak foot, because it is weak in the sense that it is in danger of progressive deformity and because the sensation of weakness is the earliest and most constant symptom. Many weak feet, in the early stage at least, would not be recognized as deformed (flat) feet. Flat foot is therefore a misnomer, and it is an especially unfortunate term, in that it calls attention to deformity rather than to disability. The term weak foot will be used therefore to include all varieties of disability of the foot which are characterized by the habitual attitude of inactivity, of which the more advanced types might be properly described as flat feet.

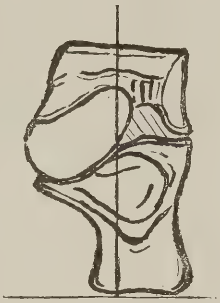


FIG. 2120.—The Normal Relation of the Astragalus to the Os Calcis.

The Anatomy of the Weak Foot.—As has been stated, a persistence of the attitude of rest or inactivity is characteristic of the weak foot. This attitude in which the weight falls upon its inner border is sometimes called pronation or eversion of the foot, and, when at all marked, it might be described properly as valgus. This latter term is, however, usually associated with more advanced or fixed deformity (talipes) and it is therefore rarely applied to the disability under consideration.

One may analyze the attitude and the deformity of the weak foot somewhat as follows. 1. The leg is displaced inward so that the weight falls upon the inner side of the foot. 2. The leg is rotated inward so that a line drawn through its centre prolonged from the crest of the tibia, instead of falling over the second toe, now points inside the great toe, or even over the centre of the internal border of the foot (Fig. 2119).

It has been stated that under normal conditions, in the act of passive weight bearing, the astragalus rotates downward and inward upon the os calcis, depressing its anterior and internal border until the movement is checked by the strong ligaments connecting the bones (the calcaneo-scaphoid, the deltoid, and the interosseus); in other words, the leg has a tendency to slip downward and inward from off the foot. In the weak foot this inclination has become an accomplished fact, for the normal movement has become so exaggerated by the distention of the ligaments and by the weakness of the supporting muscles that a partial dislocation has taken place (Figs. 2120, 2121). The astragalus has rotated and slipped far to the inner side of its normal position and is in an attitude of exaggerated rotation and moderate plantar flexion, so that its head can be plainly felt on the internal border of the foot. The anterior extremity of the os calcis is depressed and turned slightly inward and its internal border is lowered. The scaphoid bone is lowered together with the head of the astragalus, although to a less degree, and has been forced farther away from the os calcis, and with it the entire border of the foot is depressed also. Thus the depression of the arch, the third element in the deformity, is always accompanied by a bulging inward of the inner side of the foot. The foot is, as it were, broken in the centre, the posterior division having turned inward and downward; that is, the astragalus has rotated inward and downward to an extreme degree and has slipped from off the os calcis. The latter bone, although forced outward in its relation to the astragalus, still turns inward slightly, while the fore foot in its relation to the leg and to the posterior divisions of the tarsus is greatly abducted. The dislocation may be so extreme that the entire sole of the foot rests upon the ground, and a callus even may be found at the point that usually represents the high-

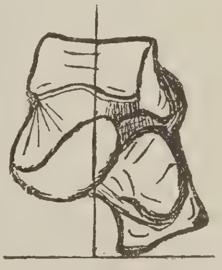


FIG. 2121.—The Relation of the Astragalus to the Os Calcis in the Confirmed Weak Foot.

est point of the arch, which now supports the greatest burden.

In this change of relation between the bones, the arched part of the foot, or waist, appears much broader than normal, even broader than the front of the foot; the heel projects, the external malleolus is depressed and carried forward by the rotation of the leg and is much less prominent than normal; the internal malleolus is more prominent and with the astragalus it overhangs the bearing surface of the sole. The foot, considered as a mechanism, is twisted and out of gear, its motion is therefore very much restricted. It is manifestly impossible for the patient to adduct the fore foot, that is, to turn it inward about the head of the misplaced astragalus. Plantar flexion is also much limited because of the permanent position of adduction and plantar flexion that the astragalus has assumed. Dorsal flexion, on the other hand, may appear to be abnormally free, because the fore foot is abducted and slightly dorsiflexed upon the head of the astragalus. When, however, the displacement is reduced adaptive shortening of the calf muscle becomes evident in many instances.

Supposing the foot to have been normal before it began to break down, it is apparent that such deformity could not have been acquired without marked changes in its internal structure. In a general way these changes have been indicated by the description; the ligaments on the internal aspect of the foot and of the ankle joint are weak and distended; the unused portion of the articular surfaces of the joints may be denuded of cartilage, while new facets may have formed to accommodate the changed relation of the bones—as, for example, at the junction of the external malleolus with the os calcis. Evidence of injury and of abnormal pressure may be found in thickened periosteum and in formation of osteophytes, while the internal structure of the bones has been changed as well, to adapt itself to the new conditions. The muscles which are no longer used in the leverage function, the plantar flexors and adductors, have become atrophied—a change that is made evident by the shrunken calf. The muscles on the inner border of the foot have been overstretched, while those on the upper and outer part have become shortened and contracted. Such a foot represents an extreme, it may be an irremediable, degree of deformity. The machine is completely broken down; it can no longer perform its proper function; it is even less efficient than the wooden foot, because use is attended by discomfort.

The disability and its accompanying deformity are found in every grade of severity. Pain begins when, the support of the muscles being insufficient, the ligaments begin to give way under strain, allowing the bones to occupy an abnormal relation to one another. It is evident therefore that the individual in whose foot the arch is accentuated and whose ligaments are firm, may suffer from the symptoms of strain long before the arch has been depressed or deformity has become apparent; also that the lateral inward bulging, characteristic of advancing deformity, must in such a case be very great before the astragalus can reach the ground and the arch be completely flattened. On the other hand, if the individual has inherited a low arch, or if, as the result of weakness in early life, the arch has been depressed or has never developed, accommodative changes in the bones will have taken place during growth, so that the flat foot of this type will not be attended with as much change in its relation to the leg, and therefore disturbance of function, as in the typical case that has been described. This latter class of cases exemplifies the popular type of flat foot that may exist without pain or disability.

It is very evident that the lowering of the arch is a secondary element of the deformity and that the popular significance of flat foot, as an inherited and irremediable weakness, is most misleading. It is misleading also in that in the most painful type of weak foot there may be practically no lowering of the arch, as shown by an imprint of the sole, while the actual flat foot may exist without symptoms.

As has been stated, there is one feature common to every grade of the so-called flat foot: the foot regarded as a machine is weak, as compared with the normal standard—weak because of the persistence of the attitude of rest and relaxation, as contrasted with that of activity and strength, and weak because the proper relation between the power and the fulcrum is changed. Even the inherited flat foot, or the flat foot which has never caused symptoms, is weak, in the sense that in use it lacks the spring and elasticity characteristic of the perfect machine.

The term weak foot may be used then to indicate all types of the disability. In one weak foot the arch has disappeared; in another weak foot the arch is of normal depth, but the foot is abducted or pronated in its relation to the leg. In one case the deformity appears only under weight; in another the foot is held rigidly in the deformed position by muscular spasm. In one instance there may be great deformity without pain; and in another disabling weakness and pain without deformity. In one case the foot is unable to perform its functions because of its inherent weakness, in another the disability may be due simply to the improper use of a normal structure. In all cases, however, disability as exemplified by the symptoms of pain and weakness is due to a disproportion between the burden or strain that is put upon the foot and the ability of the mechanism to perform this task.

This theory accounts for the fact that the weak foot, although very common in childhood, does not, as a rule, cause discomfort until adolescence, when the weight and strain put upon it are increased. It explains also why the foot which may be fairly normal in structure breaks down more often in later adolescence or early adult life when the continuous strain of regular occupation is undertaken. It is evident that an occupation requiring the long continuance of the passive attitude,—that of waiters, cooks, and bartenders for example,—exposes the feet to greater strain than one which permits alternation of postures, and that the symptoms are likely to be more severe and the deformity to be greater among those who are obliged to labor than among those who are not. Overwork or strain, of occupation or otherwise, may be temporarily disproportionate because of local or general weakness, as for example during pregnancy or after recovery from exhausting disease or because of local injury or disease of the foot itself or simply because of the strain of more constant use. On this theory one may very easily explain what has proved such a stumbling block for students, viz., that there is no constant relation between the degree of deformity and the severity of the symptoms; for although all flat feet are weak feet, yet all weak feet are not necessarily painful feet. Pain is not caused because the foot is flat; it is a symptom of progressive deformity, of strain and injury to the joints; it shows that the foot is becoming flat; it is a symptom of the injury that the weak or flat foot has received. The progress of the deformity may be temporarily or permanently checked at any stage, either by a removal of the exciting cause or because of the resistance of the tissues; then the pain ceases. On the other hand, this stability may not be attained until the entire sole of the foot rests upon the ground, and even then the patient may suffer from discomfort and pain.

This conception of the foot as a machine, of which grades of efficiency may be recognized, has a great advantage, since it enables one to perceive wherein a foot is weak even though the weakness causes no symptoms whatever. Thus one may prevent deformity by avoiding the extra strain that improper attitudes entail, and by strengthening the muscles on whose ability its integrity depends. Finally, from this standpoint one may better appreciate the etiological importance of improper shoes, in this as in practically all of the disabilities to which the foot is liable.

As has been stated, the symptoms of the weak foot, although similar in type, vary in severity according to the local condition and the disturbance of function, the work to be performed, and the susceptibility of the individual.

Symptoms.—The most characteristic symptom is the sensation of weakness. The patient begins to recognize as familiar, a feeling of discomfort, of tire and strain about the inner side of the foot and ankle, sometimes after long standing, a dull ache in the calf of the leg, or pain at the knee, hip, or in the lumbar region, symptoms more common in women than in men; or, after overexertion, a momentary sharp pain radiating from the point of weakness; thus the patient often dates the history of his trouble from a long walk. After a time the patient may become aware that he is accommodating his habits to his feet; he rides when he once walked; he sits when he once stood; he no longer runs up or down stairs or jumps off the street car. His feet have lost their spring as he expresses it, which means that the foot is no longer supported and controlled by muscular activity and is no longer used as a lever. Not infrequently, early symptoms are pain and sensitiveness at the centre of the heel, explained in part by the jarring heel walk which is always assumed when the foot is weak, and in part by the strain upon the attachments of the deep plantar ligaments. The patient may complain that he cannot buy comfortable shoes; the reason is that the weak foot under use is changed in shape, so that the shoe that was comfortable in the morning compresses the foot painfully at night. Thus increasing discomfort, due in part to corns, bunions, painful great toe joints, and deformities of the toes, is experienced. Coldness and numbness, congestion and increased perspiration, caused by the impaired circulation and weakness, are common symptoms in this class of cases. Actual pain is, as a rule, felt only when the foot is in use. It ceases under temporary rest or relief from disproportionate work, and it is this remittence of symptoms, together with the fact that the discomfort is usually more marked in damp weather, that leads so often to the mistaken diagnosis of rheumatism. The foot is weak and vulnerable; the patient recognizes the fact that he has what he speaks of as a weak ankle, or sprain, or gout, or rheumatism; but if he has accommodated himself to the weakness, but little discomfort is experienced. In many instances such relief or accommodation is impossible, and it is therefore among the working class that one oftener sees the rapid development of the disability and deformity. The range of motion becomes more and more restricted; the habitual attitude, at first exaggerated to deformity only under the influence of the weight of the body, becomes a permanent displacement. The weak and distorted foot is subjected to constant injury, to what may be likened to a succession of slight sprains; thus local congestion, swelling, and sensitiveness may appear together with muscular spasm, rigidity, and pain on passive motion. Because of the rigidity of the foot, which has lost the power to accommodate itself to inequalities of the surface, the patient dreads to cross a rough pavement, for every misstep is a source of pain. Another characteristic symptom is the discomfort felt on changing from a position of rest to activity. This, although it is usually present in slight degree at every stage, now becomes more prominent. The patient after sitting, or on rising in the morning, is unable to walk, but staggers and limps for several minutes, a symptom explained by the fact that when the foot is at rest there is a partial reposition of the displaced bones, which must be again forced into the deformed posture that has become habitual. The local tenderness and muscular spasm are increased by use, so that the patient may have difficulty in removing the shoe at night, and the symptoms relieved by the rest of Sunday become progressively worse during the week.

The pain and discomfort are more general in character, and are often referred to the dorsum of the foot, representing muscular rigidity and tension to the irritated plantar fascia, and to the outer side of the ankle, where the external malleolus is grinding out a facet in the projecting os calcis. The patient may now complain of discomfort in the feet and of cramps in the legs, even when in bed, and the appearance of weakness, awkwardness, and depression of spirits may be so noticeable that the case is sometimes mistaken for serious disease of the nervous system.

The appearance of such a foot has already been described, and the effect of the deformity on its function should be evident. The gait is slouchy and cloddy; the feet are simply pushed by one another in the attitude of eversion, the knees are slightly flexed and the weight is borne entirely upon the posterior segment of the foot. The muscles have atrophied, the foot is cold and congested from its continual inactivity, and it usually is bathed in perspiration. A certain range of motion remains at the ankle joint, but adduction is absolutely restricted by the shortened and spasmodically contracted muscles on the outer and upper surface. This type represents of course only the severe variety that is more likely to be seen in hospital than in private practice; and it would seem, were it not for the evidence to the contrary, which the histories of the patients present, that the nature of the trouble must be recognized at a glance, although in the milder and earlier cases the diagnosis is not always so easily made.

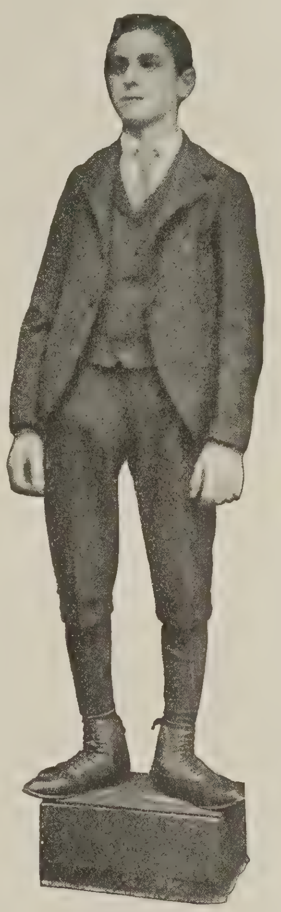


FIG. 2122.—Extreme Deformity in Adolescence.

Diagnosis.—In all cases in which weakness of the foot is suspected, a thorough and orderly examination should be made, not only of its appearance, but also of its functional ability and of the manner in which it is used. Such an examination is not merely for the purpose of confirming a diagnosis which is usually evident on inspection, but rather that the amount and character of the temporary or permanent changes in structure may be estimated.

Attitudes.—One begins the examination by noting the manner of standing and walking. The heel walk, the exaggerated turning out of the feet, the slouchy gait in which the leg is never completely extended, in which the power of the calf muscle is not applied and in which the essential postures of the foot are disused, are all elements of weakness that should be corrected whether they cause symptoms or not. The distribution of the weight of the body and the habitual use of the foot are often made evident by examining the worn shoe. If it is bulged inward at the arch or worn away on the inner side of the sole, it shows weakness. The same observations are then made on the bare feet, particular attention being paid to the line of strain or leverage. Thus, a line drawn down the crest of the tibia from the centre of the patella continued over the foot, should meet the interval between the second and third toes; if it falls over or inside the great toe, it shows that the foot is working at a disadvantage.

The contour of the foot should then be examined. Its internal border should curve slightly outward, so that if the feet are placed side by side with the toes and heels in apposition, a slight interval remains between the arches;

if this slight concavity is replaced by a noticeable convexity when weight is borne, the foot is weak. This change in contour is the earliest and sometimes the only evidence of deformity. The arch of the foot properly protected by the muscles and by a proper attitude, sinks but slightly under weight; there is a slight elasticity only, as the strain is thrown more to the inner side of the median line, and if the depression is marked it shows weakness.

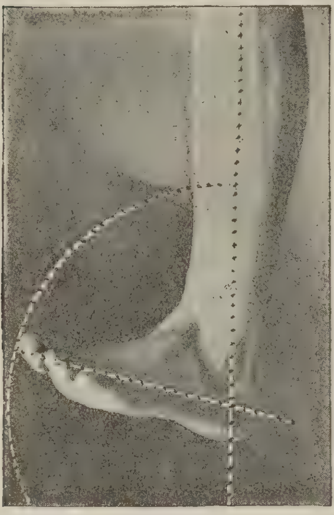


FIG. 2123.—Voluntary Dorsal Flexion.

Bearing Surface.—The exact amount of bearing surface may be shown by an imprint upon carbon paper or by smearing the sole with vaseline; then as the patient stands upon a sheet of white paper the outline of the foot should be traced, so that the relative size of the imprint to that of the foot may be shown and compared with the normal standard.

The Range of Motion.—The range of motion is next to be tested, for its limitation is one of the earliest signs of disuse of function and weakness. This range of motion varies somewhat within normal limits; it is usually greater in childhood than in adult life, greater in the slender than in the massive foot, and greater in the foot used properly than in one that is not. The first test is applied to simple dorsal and plantar flexion; the leg must be fully extended at the knee, the line of strain must be in its normal relation so that the foot is neither adducted nor abducted, and the observation must be made upon its outer border. The patient should be able to flex the foot from ten to twenty degrees less than the right angle, and to extend it from forty to fifty degrees beyond the right angle, the range of motion being from fifty to sixty degrees.

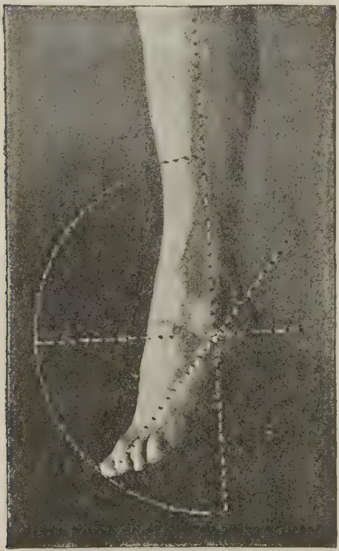


FIG. 2124.—Voluntary Plantar Flexion.

By far the most important test, however, is that of adduction or inversion of the foot, the test of the medio-tarsal and subastragaloid joints, a motion in which the os calcis is drawn forward and inward under the astragalus, as the fore foot is flexed about its head. With the leg extended as before, the foot is turned inward as far as possible. The elevation of its inner border (supination) and the turning in of the heel are shown in the accompanying figure. The actual range of adduction is somewhat difficult to measure, but it is about thirty degrees (Fig. 2125). Even the mild and early cases of weak foot usually show some limitation of this most important motion, and in many instances it is completely lost, the patient turning the entire leg in the effort to adduct the foot. The less important range of abduction may then be tested; normally it is about half that of adduction. It may be noted that the range of supination or inversion of the sole is nearly twice as great as that of pronation or eversion of the sole; in other words, the internal border of the foot can be raised twice as far from the floor as can the external border.

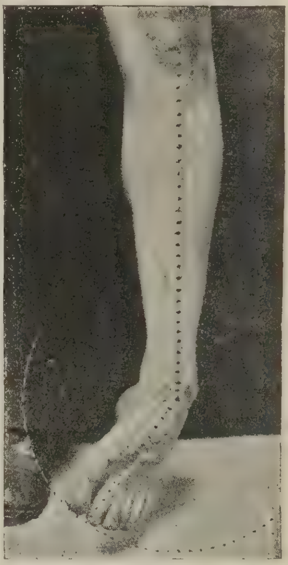


FIG. 2125.—Voluntary Adduction.

The range of passive motion is then tested. That of dorsal flexion is from five to ten degrees beyond that of voluntary motion, while passive extension, so far as it applies to the ankle joint, is about the same as the voluntary, although the fore foot may be still farther bent downward at the medio-tarsal joint. The limits of passive adduction and abduction are considerably beyond those of the voluntary range.

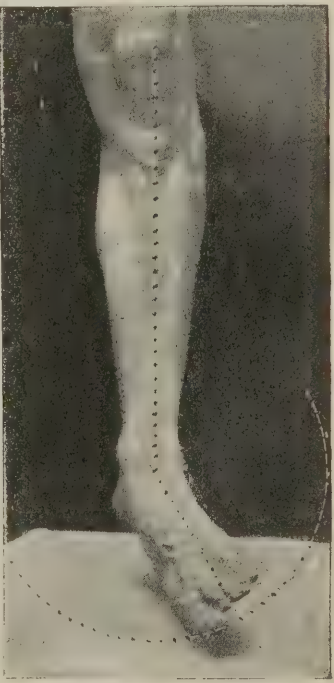


FIG. 2126.—Voluntary Abduction.

The test of passive motion serves several purposes; contrasted with the range of voluntary motion it shows the habitual use of the foot, since the motion least used is most limited. It also makes evident the slight restriction of motion and the presence of local tenderness, which, even in early cases, are usually present. Thus, if pressure be made just in front of and below the internal malleolus, at the astragalo-scaphoid junction, and if at the same time the foot be suddenly adducted, the patient will complain of pain at the point of pressure and of a feeling of constriction and tension about the dorsum of the foot, before the normal limit of motion is reached. When the foot is dorsiflexed the plantar fascia is put upon the stretch, and its condition may be noted, for a contracted and sensitive plantar fascia may cause symptoms of disability that induce, or are combined with, abduction and valgus. In other words, this mode of examination demonstrates the disability and permanent change in the machine which must be overcome before a cure can be accomplished. By it one will recognize several grades of weak foot.

Varieties of Weak Foot.—1. The normal foot improperly used, as shown by the manner of standing and walking.

2. The foot which, because of laxity of ligaments or insufficient muscular support, is forced by the weight of the body into an attitude of deformity. The foot when in use falls into an abnormal attitude of abduction in its relation to the leg, as evidenced by the inward projection of its inner border and by the overhanging internal malleolus, showing that the leg has been displaced inward on the foot. As a rule, in this class, the laxity of ligaments allows a depression of the arch, as shown by the imprint, but in other instances, although the arch seems lower because of the characteristic attitude (valgus) in which the leg as it were overhangs the foot, yet the imprint shows that there is no increase in the area of bearing surface. Indeed this may be even smaller than normal; thus an individual may suffer from so-called flat foot whose arch is in reality exaggerated.

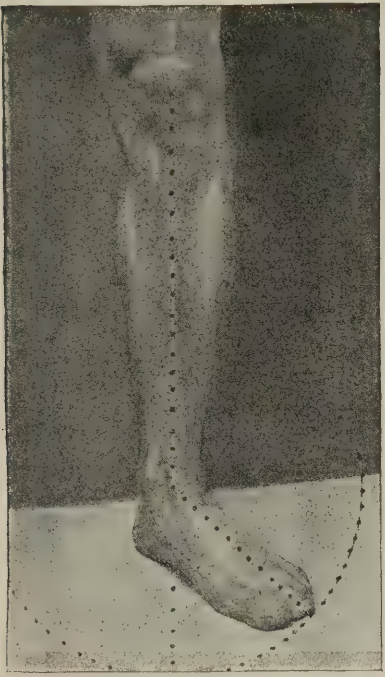


FIG. 2127.—An Attitude that Simulates Flat Foot.

3. The weak foot, which shows typical deformity under use and in which the range of voluntary motion is somewhat limited, particularly in the direction of plantar flexion and adduction. In this class forced motion causes discomfort and pain, showing a certain permanent accommodative change in structure which is not apparent when the foot is not in use. In these slighter grades of disability, the improper use of the foot, the loss of active leverage ("spring") is very evident when the patient walks.

4. The foot which presents typical and permanent deformity, whether it is in use or not, and in which the range of both voluntary and passive motion is much restricted.

This limitation of motion is an adaptation of structure to the habitual functional use and to the deformity. Such changes are first apparent in the muscles and ligaments; in more advanced cases, the articular surfaces of the bones are altered to accommodate the habitual subluxation. Added to this underlying limitation of motion there is usually a certain amount of muscular spasm, which varies in degree with the local congestion, irritation, and inflammation of the joints and tissues. In the quiescent weak foot it may be absent, but on renewed injury or overwork of the weak structure it again appears. It depends also upon the irritable condition of the overworked and contracted abductor muscles, practically the only group that retains functional power. Thus the spasm, as has been stated in describing the severe and painful type of weak foot, is greater after the day's use and relaxes somewhat during the night. The degree of muscular spasm and rigidity varies with the intensity of the symptoms. It is often greater in the early stage of the disability than in the cases in which the deformity is of long duration.

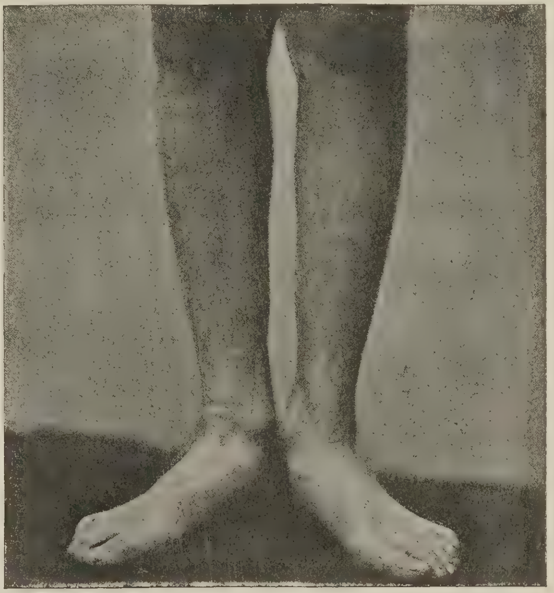


FIG. 2128.—Weak Foot in Childhood showing Habitual Abduction, without Depression of the Arch.

Two Extreme Types of Weak Foot.—1. Persistent Abduction.—In one type of rigid foot, the foot is twisted outward and upward. It may be pronated to such an extent that practically the weight is borne upon the heel and ball of the great toe. In such instances the astrag-

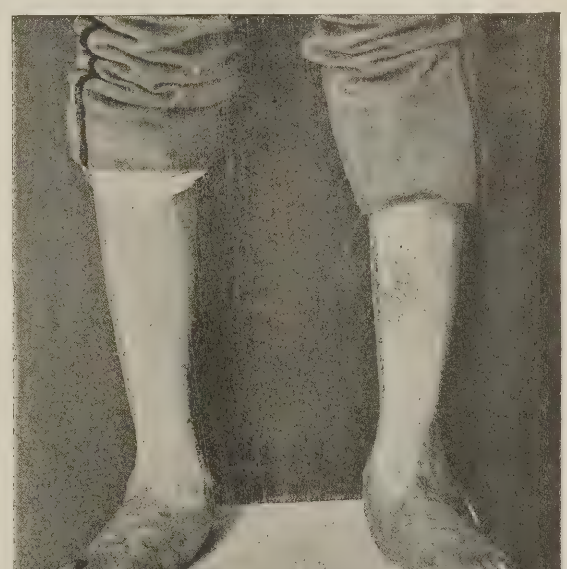


FIG. 2129.—Extreme Deformity in Adolescence; Abduction and Complete Sinking of the Arch.

alus, although rotated inward upon the pronated os calcis, is, of course, not plantar-flexed nor is the anterior extremity of the os calcis depressed. The entire foot is simply held in an attitude of extreme abduction and slight dorsal flexion, by the spasm and contraction of the flexors and abductors, so that the leg must be bent at the knee and inclined forward to bring the sole to the ground. Such extreme cases are uncommon. They are often the direct result of injury ("chronic sprain"), and when the deformity is reduced the arch will be found to be exaggerated in depth. Less extreme types of this class are often seen and they serve to emphasize the statement that the most important disability of the weak foot is due to the change from the normal relation between the leg and the foot (valgus) and not to the depression of the arch, (planus) which is, in most instances, a secondary deformity.

2. Pes Planus.—As has been stated already and as is well known, there is a type of painless deformity sometimes called pes planus. To this type the term flat foot may be properly applied because the flatness of the foot is more noticeable than the other components of the deformity that have been described. This class is probably the effect of inherited laxity of ligaments or of rachitis or other form of acquired weakness in early life, so that a normal arch was never present. Such a foot controlled by efficient muscles may be strong and serviceable, but it is nevertheless deformed, and it is doubtful if its possessor ever could attain the grace and elasticity of gait possible under normal conditions. It is said also that a low arch is normal in certain races, for example the negro, but it is certain that the American negro is not exempt from the pain and disability incidental to the broken-down foot, whether his arch was originally low or not.

It is evident that the breaking down of a properly shaped foot, provided with normal ligaments, must be attended by greater pain and disability than of one in which the arch was originally low and of which the ligaments were weak, because it is during the progression of the deformity, and particularly in its early stages, that such symptoms are most prominent. When the bones of the arch rest upon the ground or when final stability has become assured, pain may cease, and permanent accommodation to the new condition may increase the ability of the deformed member. Such an adaptation might be quickly accomplished in the foot originally flat, while in the other instance the symptoms, although remitting from time to time, might continue during the life of the sufferer.

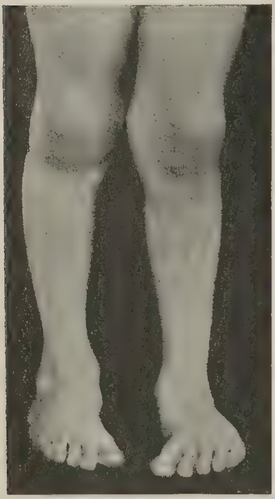


FIG. 2130.—Adduction of the Fore Foot Combined with Valgus; an uncommon type.

WEAK FOOT IN CHILDHOOD.—There can be no doubt that in many instances the origin of the weak foot may be traced to early childhood. Certainly, deformities and improper attitudes are very common at this period and it is much more likely that they are ingrown than outgrown. Actual pain from the weak foot is unusual at this age. The child may complain of fatigue and may be weak and awkward, but it is usually because of the very evident deformity, rather than because of symptoms, that advice is asked. In these cases, as in every case, the habitual attitudes and use of the feet are of the first importance.

One of the most frequent of the improper postures is that of exaggerated outward rotation of the feet, which is not only an ungraceful attitude, but a direct cause of weakness as well. The opposite attitude of inward rotation of the feet, the so-called "pigeon-toed" walk, is most offensive to relatives and friends, and it is for correction of the attitude that the child may be brought for treatment. The attitude is, in many instances, a sign of the weak foot, for on examination the bulging on the inner side, the inward rotation of the leg in its relation to the foot, and the flattened arch, show very plainly that it is the foot and not the attitude that requires treatment; in fact the attitude is, in this class of cases, really a safeguard against increasing deformity and it will correct itself when its cause is removed. Particular emphasis is laid upon this point, which is very generally overlooked, because the routine treatment of the "pigeon toes" in these cases might be the cause of direct harm.

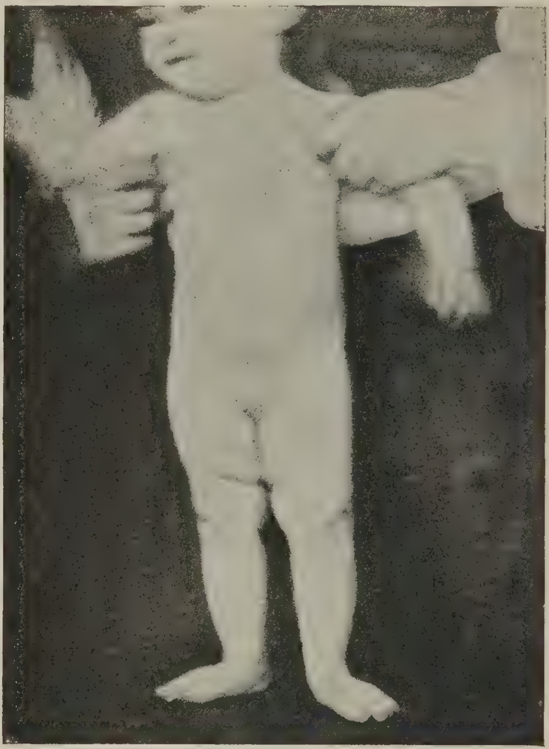


FIG. 2131.—Flat Foot in Early Childhood.

"Weak ankle" is a term popularly applied to the weak foot of childhood, in which the foot is in a position of valgus when in use, so that the shoe is worn away on its inner side. Weak ankles are very common in very young children and are often one of the results of general weakness due to defective assimilation. At this age the foot is, in addition, usually flat, although in the valgus or weak ankle of later years the arch is often normal in outline.

In older children prominent or "outgrown" joints often attract the mother's attention; the internal malleoli appear prominent because of the position of valgus, or, because of the eversion of the feet, the malleoli may strike against one another, "interfere," and thus there may be an actual hypertrophy of the projecting bones from local irritation.

Another type is the long slender foot in which the scaphoid bone is prominent because of the strain and pressure put upon it by the improper attitudes; its position is often shown by the point of wear in the leather of the shoe. In the weak foot of childhood, although restriction of voluntary and passive motion may be present, there are, as a rule, but little local tenderness and muscular spasm, and as has been stated, but little pain. Thus it differs greatly from the adult type, the reason being that the weak foot in childhood is not subjected to the strain of constant occupation or to the burden of the increased weight of the body. There is another important difference also: the foot in the adult is obliged to bear a greater burden than any other part, and although fairly normal in structure it may be overstrained. Thus in many instances the weakness of the foot may be the only disability. In childhood, on the other hand, a weak foot is very often a local indication of general weakness and loss of tone.

The direct effects of the weak and painful foot have been described in detail. It must be borne in mind that the feet are the foundation of the body, and that an insecure foundation affects the entire mechanism. General functional weakness and awkwardness, the flat chest, round shoulders or other curvatures of the spine, are often observed as accompaniments or effects of weak feet. As a rule, the systematic treatment of any form of postural weakness in childhood must include the treatment of the feet as well.

Recapitulation.—The disability and deformity of the weak or so-called flat foot are caused by disproportion between the strength of the foot and the weight and strain to which it is subjected.

The foot may be weakened by injury or disease; it may be overburdened by the body weight, or overstrained by laborious occupation, or the broken-down foot may be simply one indication of general bodily weakness. It is unnecessary to enumerate all the various factors that singly or combined lead to this disability.

It may be stated, however, that the painful weak foot as seen in adult life is in many, or most, instances the only evidence of weakness. The most constant of the predisposing causes are improper shoes, and the mechanical disadvantage to which the foot is subjected by the assumption of improper attitudes.

All weak or flat feet are mechanically weak, but all weak feet are by no means painful feet. Pain, the symptom of overstrain or injury, bears no definite relation to the degree of deformity.

In certain instances, exaggeration of the arch may be combined with persistent abduction of the foot; in others, the flattening of the arch may be the most noticeable deformity, but in most cases, the two are combined in varying degree. And as each deformity is an evidence of weakness, it seems hardly necessary to make a radical distinction between the two.

Treatment.—The principles of the treatment which leads to the permanent cure of the weak foot are very simple, but their application varies somewhat according to the grade and duration of the disability. The object of treatment is so to change the weak foot that it may conform, not only in contour but in habitual attitudes and in power of voluntary motion, to those of the normal foot, because cure is impossible until function is regained. The first step must be, therefore, to make passive motion free and painless to the normal limit. In other words, the obstructions to the motion of the machine must be removed before the power can be properly applied; for normal function is manifestly impossible, while motion is restrained by deformity or pain or by adhesions or contractions.

The weak foot, because of inefficient ligaments and muscles unable to hold itself in proper position, must be supported, in many instances, until regenerative changes have taken place in its structure. Such support is necessary to retain the joints in proper position, and to hold the weight and strain in normal relation to the foot. When these essentials are provided, the patient may cure himself by the proper functional use of the foot, and by the avoidance of attitudes that place it at a disadvantage.

It may be well to describe first the treatment that must be applied to all classes of weak foot in which a cure is to be attempted, and which by itself is sufficient in the milder types, before calling attention to the modifications that may be necessary in special cases.

The Shoe.—In practically all cases it will be necessary to provide the patient with a proper shoe, for the shoe is usually the direct cause of the minor deformities, and the indirect cause, in many instances, of more serious disability. Indeed most of the deformities and disabilities of the foot are incidental to civilization and are confined to the shoe-wearing people.

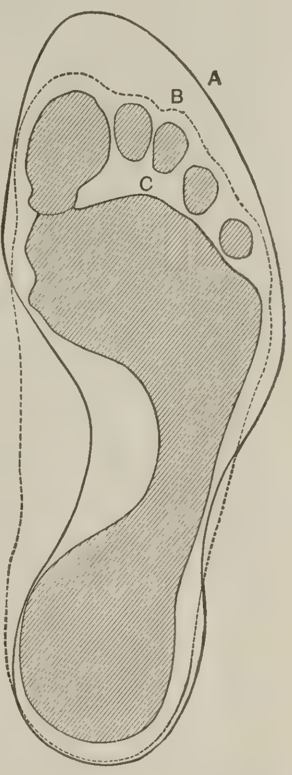


FIG. 2132.—The Proper Relation of the Sole to the Shape of the Foot. *A*, Outline of sole; *B*, outline of foot; *C*, imprint of foot.

The direct effect of the ordinary shoe is to lessen the size and balancing power of the fulcrum by cramping the toes together while the high heel throws more strain upon the arch and the ankle. Indirectly it causes deformities, corns, bunions, and the like, which serving to make active movement or leverage painful, induce the habitual assumption of the passive attitude which predisposes to deformity.

The proper shoe should contain sufficient space for the independent movements of the toes. This motion is illustrated in the walk of the barefoot child. As the weight falls on the foot the toes expand, and as the body is raised on the foot they contract. The important leverage action of the great toe and the support afforded by it to the arch of the foot have already been mentioned. The shape of the sole should correspond to the shape of the undistorted foot and the heel should be broad and low.

The prevention of distorted toes and the discomforts that result from the abuse of the foot is of great importance in childhood, but, unfortunately, little children are often seen wearing shoes of the shape usually assumed at years of discretion. In this regard, girls suffer more than boys, as women do more than men. The girl who may have worn comparatively harmless shoes until the age of ten years or thereabouts, changes suddenly to the high heel and narrow sole and the process of distortion begins, the amount of distortion and the degree of discomfort depending on the amount of work required of the foot. Wide soles without heels should be worn as long as possible by children because of the greater stability and because the high heel limits the necessity for, and therefore the use of, the entire range of motion of the foot and ankle.

A simple expedient in the treatment of the weak foot and an aid in balancing it properly, is to make the inner border of the sole and heel of the shoe slightly thicker in order to throw the weight toward the outer side of the foot. This is of especial importance in the treatment of the slighter degrees of what is known as weak ankle, but it is always of service in the treatment of any grade of weak foot.

Attitudes.—When the patient is provided with a proper shoe, his attention is called to the attitudes that protect the foot from strain. He should endeavor to hold the feet nearly parallel to one another in walking and to throw the weight as far as possible on the outer border of the sole of the shoe. The significance of the bulging on the inner side of the foot is pointed out to him and how this may be prevented by voluntarily inclining the weight to the outer side of the foot and by aiding the arch by the power of the great toe.

The importance of leverage is shown him, he is told that he must try to press down the sole of the shoe with his toes and employ the active lift of the calf muscles by fully extending the leg and raising the body on the foot from time to time. Finally, he must avoid long continuance in one position, especially the passive posture which simulates the attitude and deformity of flat foot. In short, he must be instructed in the mechanics of the foot and taught how the weak foot may be protected and strengthened.

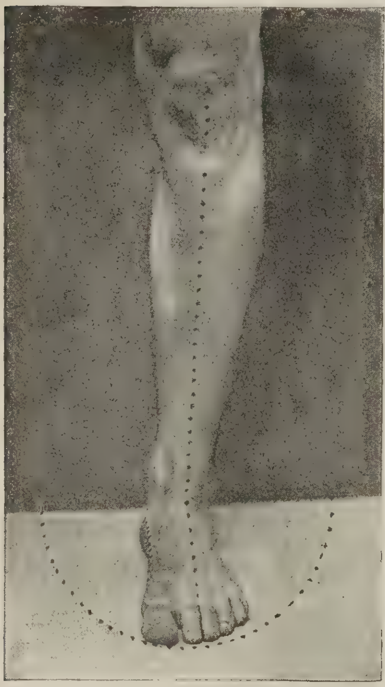


FIG. 2133.—Illustrating Voluntary Protection of the Foot from Over-Strain. (Compare with Fig. 2127.)

Exercises.—It is important also to demonstrate to the patient the normal range of motion of the foot, a range which if restricted must be regained by voluntary and passive exercise. Voluntary exercise should be devoted to strengthening the adductors and plantar flexors; thus the foot should be extended, adducted, and supinated over and over again at every opportunity. Tip-toe exercises are particularly useful. The patient holding the feet parallel to one another, or better in inward rotation, raises the body on the toes from twenty to one hundred times, the limbs being fully extended at the knees, resting in the intervals on the outer border of the feet. The best of all exercises is, however, the proper walk, in which at each step the leverage power of the foot is employed and in which it passes through the proper alternation of postures.

Treatment by massage and special gymnastic exercises is, of course, of benefit, if the patient can command it, although by no means essential to the cure.

Support.—In many instances the simple treatment that has been outlined is all that is required and the symptoms of tire and strain are quickly relieved. In the more advanced type of disability the patient is not able to prevent deformity voluntarily; consequently a support is necessary to hold the foot in proper position and to relieve discomfort. It is usually necessary in the treatment of the weak and flat foot of childhood, because one cannot command the aid of the patient.

In selecting a support for the weak foot the nature of the deformity that is to be prevented must be borne in mind. The acquired flat foot, for example, is not a direct breaking down of the arch, as is usually taught, but a lateral deviation and sinking—a compound deformity, as has already been described. Thus a brace to be efficient must hold the foot laterally as well as support the arch. In fact, as has been stated, the prevention of valgus is far more important than the direct support of the arch. The brace must not prevent the normal motions of the foot, and thus interfere with the increase of muscular strength and ability, on which ultimate cure depends.

The supports that are ordinarily employed do not fulfil the conditions; the pads and springs placed beneath the arch are intended to support it by direct pressure without regard to the lateral distortion; they are usually ill-fitting and are often of such length and shape as to splint the foot and thus prevent its motion. Leg braces which more directly control the valgus do not often hold the foot accurately, and their weight and unsightliness are fatal objections to their use in the early cases, in which prevention of subsequent deformity is of such importance.

A brace should never be applied to a deformed and rigid foot because it is not able to shape itself to the support; the spasm and rigidity must be first relieved by preliminary treatment, as will presently be described.

The Construction of the Brace.—If a brace suitable for meeting these conditions is to be constructed, it is necessary to provide the mechanic with a plaster cast of the foot, taken in the attitude in which one wishes to support it. Such a model may be easily and quickly made in the following manner:—

The Plaster Cast.—Seat the patient in a chair; in front of him place another chair of equal height; on it lay a thick pad of cotton batting and cover it with a square of cotton cloth. Put about a quart of cold water into a basin and sprinkle plaster of Paris on the surface until it does not readily sink to the bottom; then stir. When the mixture is of the consistence of very thick cream pour it upon the cloth. The patient's knee is then flexed and the outer side of the foot, previously smeared lightly with vaseline, is allowed to sink into the plaster, and the borders of the cloth being raised the plaster is pressed against the foot until rather more than half is covered. The foot should be at a right angle with the leg and the sole should be in the plane perpendicular to the seat of the chair. As soon as the plaster is hard, its upper surface is coated with vaseline and the remainder of the foot is covered with plaster; the two halves are then removed, smeared lightly with vaseline and bandaged together. The interior is dampened with soapsuds and is then filled with the plaster cream. In a few moments the plaster shell may be removed and one has a reproduction of the foot, which, when properly made, should stand upright without inclination to one side or the other. In many instances it will be of advantage to deepen in the plaster model the inner and outer segments of the arch, in order that the arch of the brace may be slightly exaggerated, especially at the heel, so that the depression of the anterior extremity of the os calcis may be prevented.

The Brace.—Upon the model, the outline of the brace is drawn as illustrated in the diagrams. The best sheet steel, 18 to 20 gauge, cut after the pattern is moulded upon it and tempered, so that, as it is applied for the purpose of preventing deformity, it may be practically unyielding to the weight of the body.

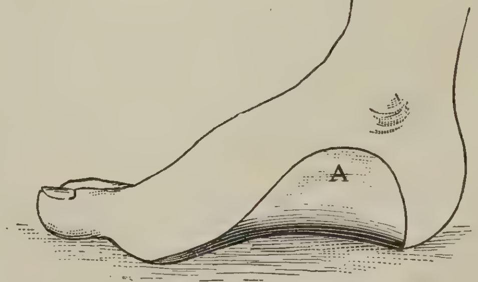


FIG. 2134.—*A*, The Astragalo-Scaphoid Junction.

It will be noted that the brace clasps the weak part of the foot and holds it well together; the broad internal upright portion covers and protects the astragalo-scaphoid junction, rising well above it. The external arm covers the calcaneo-cuboid junction and the outer aspect of the foot to a height sufficient to hold the foot securely. The sole part provides a firm, comfortable support, yet, reaching only from the centre of the heel to a point just behind the metatarso-phalangeal joint of the great toe, it does not restrain the normal motions of the foot.

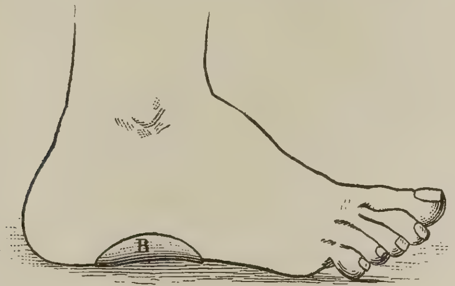


FIG. 2135.—*B*, The Calcaneo-cuboid Junction.

The brace may be nickel-plated and japanned, which makes a smooth finish, or tin-plated, which is a rather more durable covering. It may be covered with leather or an inner sole may be placed on its upper surface; but this is not usually necessary. As it is fitted to the foot it finds and holds its own place in the shoe, so that no attachment is required; thus it may be changed from one shoe to another. Not only does it hold the foot laterally and from beneath, but there is an element of suggestiveness in the slight leverage action which is very important. The patient, instructed to throw his weight upon the outer side of the foot and wearing a shoe which has been tilted in the same direction by thickening the inner border of the sole and heel, presses down the external arm and thus lifts the internal flange against the inner side of the foot, which is instinctively drawn away from the pressure and thus toward the normal contour. Thus he no longer everts the foot in walking because of the discomfort, and he is not likely to assume the passive attitude because of the suggestive lateral pressure of the support. This brace is therefore, when properly adjusted, a positive aid in the physiological cure as contrasted with the negative action of the ordinary sole plate.

The shape of the brace, in general like that of the diagram, may be modified in certain cases; for instance, the entire internal aspect of the foot may be weak and must be covered by the internal flange. In very heavy subjects the sole portion must be made larger, or other slight modifications may be necessary. If any portion of the rim of the plate causes discomfort, the edge may be turned away slightly at the point of pressure by a wrench. After a few days the patient no longer notices the presence of the brace, and as its presence in the shoe is not evident, it may be worn indefinitely. It is usually necessary to wear it for from three months to a year or longer, according to the condition of the part and the use to which the feet are put. The brace, properly made and adjusted under the proper conditions, causes no more pressure or discomfort than a well-made shoe, for its principle is quite different from that of ordinary supports that are in common use, to which this objection has been made. This brace supports the arch primarily by preventing abduction, consequently its pressure is first felt upon the lateral aspect of the foot, a pressure that the patient can relieve by improving the attitude. The brace should provide support when necessary, and at all times suggest and enforce a proper attitude; it is, however, but one of the essential factors in the general scheme of treatment.

In the treatment of children, passive movements of the foot should be carried out in all directions, but particularly in dorsal flexion and adduction to the full limit, at morning and at night, until the child has regained the normal muscular power and ability. Special gymnastics and massage are always desirable and they may be necessary in certain cases. Bicycling may be cited as one of the best, and roller skating as one of the worst, exercises for the weak foot. A year is about the time required for the cure of the weak foot in childhood, although attention to the shoes and the attitudes must be kept up indefinitely.

THE RIGID WEAK FOOT.—One may now contrast with these mild types of weakness that have been described, those cases of extreme deformity in which the symptoms are disabling and in which the foot is rigidly held in the deformed position by muscular spasm. Such cases, often considered hopeless as regards a cure or even relief, are in reality the most satisfactory from the remedial standpoint, and in no other type of painful deformity can so much be accomplished by rational treatment as in this class. The deformity must be considered as a dislocation, in which the astragalus has slipped downward and inward from off the os calcis, which in turn is tipped downward and inward and into a position of valgus. The remainder of the foot is turned outward, so that the relation of the fore foot and the leg is entirely changed; in fact the fore foot is almost entirely disused.

Corresponding to the duration of the disability, one finds the accommodative changes in the soft parts and in the bones, but such changes are by no means as marked as those recorded in the reports of autopsies which have been made in cases of advanced and irremediable deformity. In fact, by far the greater number of patients are young adults in whom the extreme deformity is of comparatively short duration, and in whom complete cure is possible.

In the treatment of such a condition, one must first reduce the dislocation and overcome the obstacles that contracted muscles and ligaments may offer to free and normal motion. Then rest must be assured to the injured and congested parts in order to relieve the patient from the pain that he has suffered so long.

Forcible Over-Correction.—By far the most effective treatment is forcible over-correction of the deformity, under anæsthesia. When the patient is under the influence of the anæsthetic the muscular spasm relaxes, and it will be seen that this accounts for about half the restriction of motion, the remainder being caused by the adaptive changes that have been mentioned. One now endeavors to overcome this residual obstruction and to assure the patient against a relapse, by fixing the foot in the position of extreme adduction and supination, the attitude directly opposed to that which has become habitual.

This is the object of forcible over-correction as the first step in the systematic repair of the disabled mechanism. Its principle must not be confounded with forcible correction carried out with the object of simply remoulding the arch of the foot, or in which the simple correction of the deformity is the object in view.

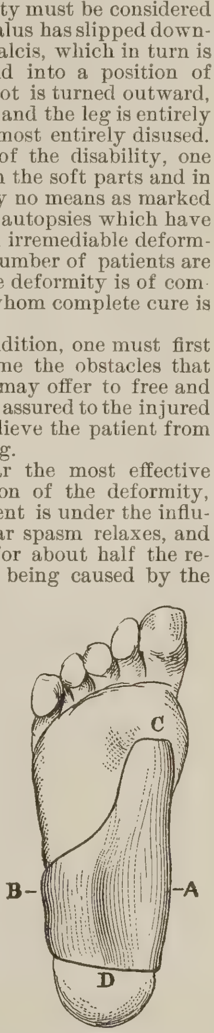
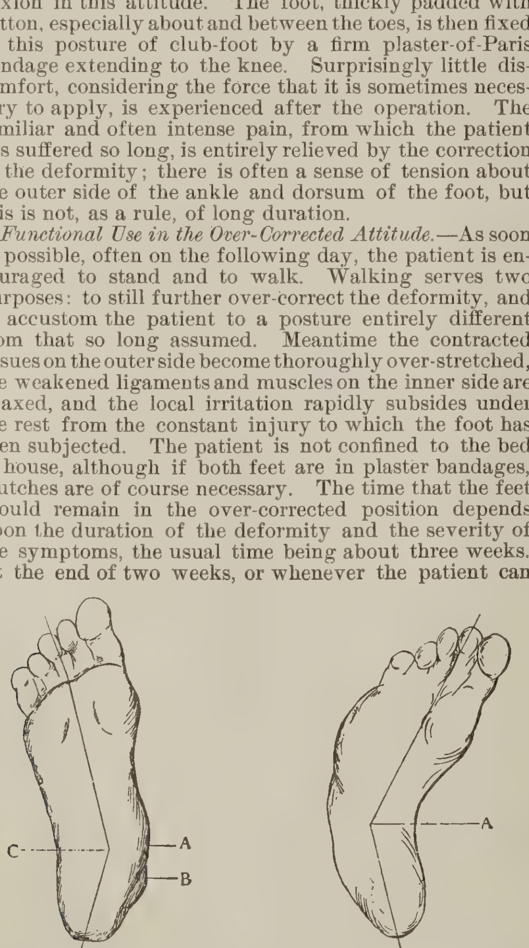


FIG. 2136.—*C*, The Metatarso-Phalangeal Joint; *D*, the centre of the heel.

One first extends the foot forcibly, then flexes it to the normal limit, then abducts and adducts, the different motions being carried out over and over, until the rigid foot has become perfectly flexible. In cases of long standing it is often necessary to draw the patient to the end of the table so that the foot may be taken between the knees, in order to supply the required force by the thigh muscles. This forcible manipulation is accompanied by the audible breaking of adhesions, and the complete disappearance of the deformity. In certain instances it will be necessary to divide the tendo Achillis; when, for example, the range of dorsal flexion is limited by resistant accommodative shortening of the calf muscles, or when there have been very great pain and tenderness at the medio-tarsal joint, and it is desired to remove the strain of the calf muscle completely; traumatic cases come especially under this head. In other cases the peronei tendons may be divided if they offer especial resistance to adduction. Tenotomy has one great advantage: it necessitates longer fixation in the plaster bandage, and gives the patient the benefit of rest and the opportunity for prolonged after-treatment. When the passive range of motion has been regained, the foot is turned downward, then inward and upward into the position of extreme varus. By this manipulation the os calcis is drawn under the astragalus and thrown into the supinated position, and the scaphoid is flexed about and under the head of the astragalus, which is then lifted to the limit of normal flexion. The attempt is always made to bring the extreme outer border of the inverted foot up to a right angle with the leg, which is the limit of normal flexion in this attitude. The foot, thickly padded with cotton, especially about and between the toes, is then fixed in this posture of club-foot by a firm plaster-of-Paris bandage extending to the knee. Surprisingly little discomfort, considering the force that it is sometimes necessary to apply, is experienced after the operation. The familiar and often intense pain, from which the patient has suffered so long, is entirely relieved by the correction of the deformity; there is often a sense of tension about the outer side of the ankle and dorsum of the foot, but this is not, as a rule, of long duration.

Functional Use in the Over-Corrected Attitude.—As soon as possible, often on the following day, the patient is encouraged to stand and to walk. Walking serves two purposes: to still further over-correct the deformity, and to accustom the patient to a posture entirely different from that so long assumed. Meantime the contracted tissues on the outer side become thoroughly over-stretched, the weakened ligaments and muscles on the inner side are relaxed, and the local irritation rapidly subsides under the rest from the constant injury to which the foot has been subjected. The patient is not confined to the bed or house, although if both feet are in plaster bandages, crutches are of course necessary. The time that the feet should remain in the over-corrected position depends upon the duration of the deformity and the severity of the symptoms, the usual time being about three weeks. At the end of two weeks, or whenever the patient can support the weight upon the plaster bandage without a sensation of discomfort, it is removed; the foot is placed in the normal attitude and a cast is taken for the brace. Immediately after this is done the foot is returned to the club-foot position, and the plaster bandage is re-applied. When the brace is ready the plaster bandage is finally removed; the foot is now in good position, and in many instances the arch is exaggerated in depth. For the first few days, prolonged soaking in hot water or the use of the hot-air bath, with subsequent massage, at intervals during the day, will be found useful in overcoming the swelling and local tenderness that may persist. It is always insisted that a new shoe of the Waukenphast pattern shall be obtained, the sole and heel of which are raised a quarter of an inch on the inner border, to aid the action of the brace in the balancing of the weak foot. When the shoe is removed at night, the patient is instructed to turn the toes in and to bear the weight on the outer side of the foot until it has regained its strength; in other words, the deformity is never allowed to recur.



FIGS. 2137 AND 2138.—Illustrating Forcible Correction of the Deformed Foot. *C*, Medio-tarsal joint; *A*, the scaphoid bone; *B*, the internal malleolus.

Systematic Manipulation.—The systematic treatment is then begun by the surgeon and the patient, the first essential being the attainment of free and painless passive motion in all directions. These motions, which have been so long restrained by deformity, cannot be regained without effort, and during this critical stage treatment must be carried out by the surgeon himself; if he trusts to the patient or to his friends, a cure is out of the question. At least once a day the full range of motion is tested. Three motions, abduction, flexion, and extension, are usually free and painless; but the fourth, that of adduction, is almost invariably resisted by the same quality of muscular rigidity that was present before the operation. By far the most effective method of overcoming this resistance is conducted as follows. The patient being seated in a chair, the surgeon sits or stands before him. Let us suppose that the left foot is to be adducted, or, as the patients express it, twisted. The surgeon places the foot between his knees; his left hand encircles the heel, the fingers grasping the projecting os calcis and tendo Achillis; the ball of the palm lies against the medio-tarsal joint on the inner aspect of the foot; the right hand grasps the outer side of the fore foot and toes; then by steady pressure of the thigh muscles, the fore foot is forced downward and inward (adducted and supinated) over the fulcrum formed by the projecting palm which lies upon the left knee, the fingers holding the heel steadily in place. This inward twisting is at first resisted by a mixed voluntary and involuntary muscular spasm, which gradually gives way under steady pressure. When the limit of adduction has been reached the foot is firmly held until all pain has subsided. Then the patient is instructed to attempt voluntary movements while the foot is guided by the hands: in other words, the patient attempts to adduct the foot while the surgeon supplies the power, which, in all cases of this type, has been completely lost. This passive manipulation to the extreme limit of normal adduction, plantar and dorsal flexion, is continued from day to day until there is no longer a sensation of pain or tension; for as long as there is the slightest spasm or painful restriction, so long is the voluntary motion limited, cure delayed, and relapse of deformity probable. During active treatment the patient, by the use of massage, active and passive motion, is constantly working to one end, namely, to regain the lost power of voluntary adduction.

The time necessary to rest the feet, to overcome the local irritation and muscular spasm, to regain, in part at least, the range of passive motion, and to place the patient in the same position as regards a cure as that of the milder type of deformity, is from three to six weeks. Usually the patients are told that a month will be necessary, and that at the end of that time they may return to work, free from pain and from danger of relapse, and that the feet will constantly grow stronger under the work which before was too great for their strength. The time necessary to re-educate the adductor muscles in their proper function depends, in great degree, upon the intelligence and persistence of the patient. Although in after-treatment massage and special exercises are of benefit, the essentials are very simple; they are, an effective brace, a proper shoe, and the passive manipulation that has been described, until its object has been attained;

the proper walk, the best and easiest of exercises; and finally, one must force into the patient's understanding the method of protecting the weak foot by the alternation of strain and by the proper postures.

OTHER VARIETIES OF RIGID WEAK FOOT.—The foot which is fixed in the abducted position without depression of the longitudinal arch, is simply one variety of the rigid weak foot, and should be treated in the same manner.

It may be stated also that a very large proportion of the so-called chronic sprains of the ankle are of this type, and that the disability will yield very readily to treatment conducted for the purpose of restoring impaired function, in the manner that has been indicated.

There are other cases in which the deformity of flat foot is complicated by rheumatoid arthritis or chronic rheumatism, of which the evidence is seen in various joints, but in which the pain and discomfort seem to be concentrated in the feet, which are absolutely stiff and deformed. In such cases one can hardly expect a complete cure, but although the function of leverage may not be regained, still one may hope, by overcoming the deformity, to hold the weight of the body in its proper relation to the foot, so that the pain of a progressive dislocation may not be added to the pain of disease. In a number of instances, forcible correction has been employed by the writer in cases of this type, and in all the improvement in the general condition, consequently in the resistance to the disease, after the relief of the local pain and discomfort, has been very great.

Between the two classes of cases, the mild and the severe, one finds every grade of deformity. All cases in which there are marked muscular spasm, local tenderness, and swelling, require temporary rest, in many instances simply rest from functional use combined with massage; in others rest in a plaster bandage in the adducted position. In the milder and ordinary class of cases, the use of a brace and shoe will alone relieve spasm and pain, and the range of motion can usually be regained by manipulation, passive motion, and by the proper use of the foot.

Occasionally, even in childhood, one may encounter marked limitation of normal motion, particularly in dorsal flexion, not due to pain and muscular spasm but to actual shortening of muscle. This may be the accommodative shortening that is characteristic of long-standing deformity; in other instances it would appear to be the result of a slight and unnoticed neuritis or anterior poliomyelitis, which has resulted in muscular inequality. If the contraction does not yield readily to manipulation or to mechanical stretching, forcible correction, and if necessary tenotomy, should be employed in the manner already described; for whatever may be the theory of its causation, it is again emphasized that obstruction to motion in any direction must be overcome before a complete cure is possible.

Adjuncts in Treatment.—It must be apparent that in many instances the cure of the weak foot is out of the question, either because of the want of energy or opportunity on the part of the patient, or because of the local or general conditions, types familiar in out-patient practice. In such cases, raising and strengthening the inner side of the shoe by the wedge-shaped leather sole, as used by Thomas, splints the painful foot and aids in relieving the strain. If the symptoms are more acute the adhesive plaster strapping, as advocated by Cottrell and Gibney for the treatment of sprains, is often of service, although it is applied in a different manner, and with a somewhat different object in view. One end of a strip of adhesive plaster, about fifteen inches long and three inches wide, is applied to the outer side of the ankle just below the external malleolus; the foot is then adducted as far as possible and the band is drawn tightly beneath the sole and up the inner side of the arch and leg, and is stayed in this position by one or two plaster strips about the calf. Narrow plaster straps are then applied about the arch and ankle, in the figure-of-eight manner, and a bandage is applied. The object of the dressing is to aid in holding the foot in the proper position by the support and suggestiveness of the plaster, and to provide the firm compression about the arch that is always agreeable to the sufferer from weak foot. This treatment combined with the built-up shoe, and with the corrective manipulation that has been described, is often very effective in overcoming the acute and disabling symptoms of the weak and injured foot, which are, as has been stated, often the result of extra strain or injury, in other words, a sprain of a weak foot. Consequently when these symptoms are relieved, the patient, who has become habituated to the weakness and deformity, considers himself cured.

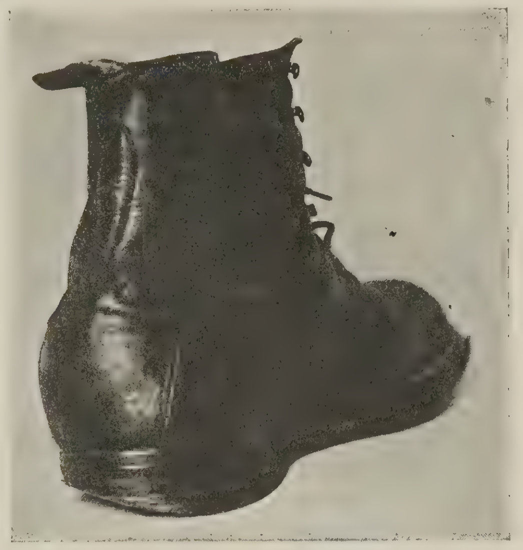


FIG. 2139.—The Internal Border of the Shoe Elevated According to Thomas' Method.

Operative Treatment.—The various cutting operations for the relief of flat foot do not call for extended comment. The typical operation, the removal of a wedge from the astragalo-scaphoid region, aims at removal of deformity simply; functional cure is made impossible by the destruction of the medio-tarsal joint. It would hardly seem possible that adhesion between the astragalus and scaphoid bones could for any length of time withhold a recurrence of deformity of the nature and origin of flat foot, and in all cases that the writer has examined in which this operation has been performed, there were still local tenderness and muscular spasm and even relapse of deformity. The operation of advancement of the posterior extremity of the os calcis, as proposed by Gleich, in order that it may be placed in a relation to the leg somewhat like that of a Pirogoff amputation, offers little hope of ultimate cure, for as the disability is not due to primary depression of the arch, it can hardly be cured by exaggerating its depth in this manner. The most innocent and rational of the operations for flat foot is the supramalleolar osteotomy of Trendelenburg, in which the bones of the leg are divided above the ankle, and the distal fragment is turned inward, with the aim of directing the weight upon the outer border of the foot. In practice, the operation is by no means always successful, while the bow-leg deformity that results, if the object is attained, is an unfortunate accompaniment of the treatment.

It may be mentioned in this connection that fracture at the ankle joint, followed by faulty union in a position of valgus, is a form of traumatic flat foot that may be cured by this operation. In operative treatment, the element of rest, necessary for weeks or months, must be taken into consideration, as explaining in part the immediate favorable effect of whatever procedure is adopted. An investigation of final results will prove, I believe, as might be predicted from the nature of the deformity and the complex structure of the foot, that there is no short and easy method by which a cure may be attained.

II. THE HOLLOW OR CONTRACTED FOOT. (Synonyms: Talipes cavus; Talipes plantaris.) The hollow foot in which the arch is exaggerated may be considered as the condition directly opposed to the flat or relaxed foot in which the arch is lessened or lost. In the latter instance the area of bearing surface is increased while in the hollow foot the bearing surface is diminished and the imprint of the sole may show that the entire weight is borne upon the heel and upon the metatarso-phalangeal region.

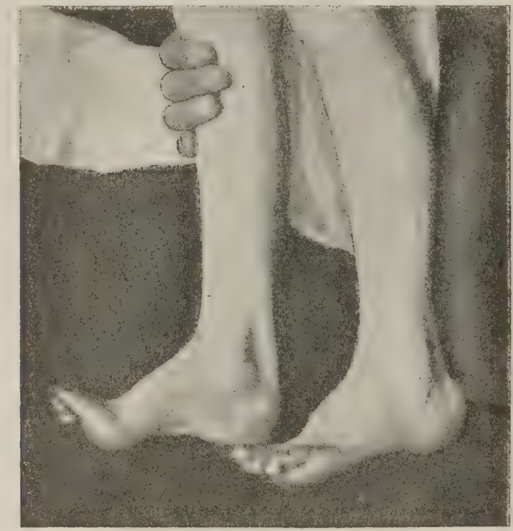


FIG. 2140.—The Contracted Foot—An Exaggerated Arch and Slight Limitation of Dorsal Flexion.

The contracted foot may be divided into two classes, the simple and the compound. In the first class the arch alone is exaggerated, "Talipes arcuatus." In the second there is a limitation of the range of dorsal flexion at the ankle joint as well, "Talipes plantaris." This latter variety was originally described by Schaffer under the title of "Non-Deforming Clubfoot" (New York *Medical Record*, May 23d, 1885).

Etiology.—The simple hollow foot may be, and often is, an inherited peculiarity. It may be induced by the habitual use of high heels or possibly by excessive exercise of the calf muscle as by professional dancers.

Compound hollow foot, in which there is limitation of the range of dorsal flexion at the ankle joint, or even slight persistent equinus, may be congenital also, but in most instances it appears to be a remote effect of a temporary weakness of the dorsal flexors of the foot, or of restriction of dorsal flexion from some other cause. This supposition is supported by the fact that the symptoms may date from a period of weakness and awkwardness following scarlet fever, rheumatism, or other infectious disease of childhood, symptoms attracting little attention in early life, but becoming more marked in adolescence or at a later period. In other instances the cause may be more direct, the slight deformity following a sprain or fracture, or it may be a result of an habitual attitude, as in patients who have been treated for disease of the hip joint by the traction appliance.

Symptoms.—The simple contracted foot may not cause symptoms; in fact it often passes as a particularly beautiful member rather than one that is deformed. As a rule, however, the patient complains of inability to buy well-fitting shoes, as the ordinary shoe does not support the arch while the upper leather presses uncomfortably upon the prominent dorsum. In cases of this type there may be actual exostoses on one or more of the projecting cuneiform bones of the dorsum surmounted by a sensitive bursa.

There is usually, in consequence of the rigidity of the foot, abnormal pressure upon the heel and fore foot, and sensitive corns or callosities at the latter point are often found. Pain beneath the great toe-joint or about the anterior metatarsal arch, which is often depressed, is a common symptom, and as a rule patients complain of discomfort in the hollow of the foot referred to the tense and sensitive plantar fascia. The gait is usually ungraceful, the patient everting the feet and walking heavily upon the heels. In many instances there is a persistent attitude of valgus, "weak ankles," and in cases of this type the most troublesome symptoms may be those characteristic of the weak foot. The symptoms described are usually more marked in the compound variety of the contracted foot than in the simple form.

On examination the nature of the affection is usually apparent. The arch is exaggerated, especially on the inner border, and the tense contracted bands of plantar fascia, usually very sensitive to pressure, can be demonstrated when the foot is dorsiflexed. In many instances there is an obliteration of the anterior metatarsal arch, the normal slight concavity being replaced by a distinct convexity, and at, or about, the head of the third metatarsal bone a sensitive callus is usually present. The prominence of the dorsum of the foot corresponds to the depth of the arch, and at this point, as has been stated, one or more of the cuneiform bones may project sharply beneath the skin. The range of dorsal flexion is often restricted at the right angle with the leg, and in this class there is usually habitual dorsiflexion of the toes, as if the direct result of the action of the accessory dorsal flexors of the foot.

Treatment.—In the mild cases of simple hollow foot the symptoms may be relieved in many instances by the use of a properly fitted shoe with a high "Spanish" arch.

If the symptoms are more persistent, a metal foot plate, modelled upon a plaster cast of the sole, may be employed, the object of the brace being to equalize the pressure on the sole, to remove the strain upon the sensitive fascia, and to lessen the pressure on the sensitive points of the anterior metatarsal arch. If the foot is habitually used in a valgus attitude, the sole of the shoe must be made thicker along the inner border in order to correct the inclination.

In addition to the supporting shoe or brace, daily forcible manipulation, with the object of stretching out the foot and increasing the range of dorsal flexion, if this be limited, is of service. The Schaffer traction brace is a useful appliance for this purpose.

If the deformity is well marked and of long standing it should be corrected by operative means. The patient being anæsthetized the fascia is divided subcutaneously and the exaggerated arch is then reduced to the normal depth by forcible manipulation with the hands, or by the use of the Thomas wrench. At the same time the slight limitation of dorsal flexion is overcome and the foot is fixed in a plaster bandage in which a thin wooden foot plate is incorporated. The patient is then encouraged to walk and he thus completes the cure by flattening the sole against the resistant sole plate. In severe cases tenotomy of the tendo Achillis may be required, but this is unusual.

III. PLANTAR NEURALGIA.—Pain referred to the hollow of the foot, combined with sensitiveness to pressure on the plantar fascia, is usually symptomatic of the hollow or contracted foot in which the fascia is subjected to abnormal tension. Occasionally it is present when the arch is weak or broken down. Sensitiveness of the fascia and pain at this point on standing are sometimes present in feet apparently normal. These symptoms may be induced by injury or by irritation or inflammation of the fascia, apparently due to infection, as it may follow influenza, typhoid fever, and the like.

Treatment.—If the foot is fairly normal in appearance, or if slight weak foot is present, the application of a well-fitting shoe may relieve the symptoms. In most instances, however, a properly fitted light steel foot plate is indicated, in order that the weight may be distributed, thus relieving the fascia from strain. If the foot is markedly contracted the fascia may be stretched or divided. (See Contracted Foot.)

IV. WEAKNESS OF THE ANTERIOR METATARSAL ARCH. (Synonyms: Anterior Metatarsalgia; Morton's Neuralgia.) Pain and discomfort referred to the metatarso-phalangeal articulations of the foot are symptoms that may be explained in most instances by an abnormal condition of the anterior metatarsal arch. Normally the anterior extremities of the metatarsal bones, although each bears its share of weight when pressure is put upon the foot in standing and walking, form an arch when the foot is not in use, the second and third bones being on a somewhat higher level than the others. In other words, there should be a certain resiliency of this part of the foot that lessens the liability to injurious pressure or strain. In many instances this resiliency is lost and one finds on examining the sole of the foot a persistent convexity in place of the normal arch. It may be noted in this connection that plantar flexion of the toes raises the heads of the adjoining metatarsal bones and increases the metatarsal arch. On the other hand, dorsiflexion of the toes lowers the arch, and as this attitude of persistent dorsiflexion of the first phalanges and consequent limitation of plantar flexion is one of the common effects of improper shoes, one recognizes the shoe as the most constant cause of weakness and of depression of the metatarsal arch.

Another type of weak arch is that in which there is, in consequence of weakness and flabbiness of tissue, an abnormal lateral expansion of the fore foot. Or again there may be apparently a local weakness of the muscles or ligaments of one of the component bones of the arch that allows it to assume an abnormal relation to its fellows.

Attention was first called to pain in this region of the foot by Dr. T. G. Morton of Philadelphia, in 1876, under the title of a painful affection of the fourth metatarso-phalangeal articulation, and as far as the symptoms of this type of what may be called anterior metatarsalgia is concerned, his description needs but little amendment. Typical cases of this class are characterized by a sudden cramp-like pain beneath the fore foot in the neighborhood of the fourth toe. It may begin as a burning pain beneath the toe or simply as a sensation of discomfort that gradually increases until it becomes unbearable. From the point of greatest discomfort the pain often radiates to the end of the toe or up the dorsum of the foot to the leg. Except in extreme cases, the pain is never felt except when the shoe is worn, and it may be relieved usually by removing the shoe and rubbing the foot. This need is so urgent that the removal of the shoe is one of the most distinctive signs of the affection. These cramp-like attacks may occur only at infrequent intervals, as for example when a certain shoe is worn, or they may recur so frequently as practically to disable the patient. After an attack of cramp the part may be sensitive for a time, and swelling even may appear, if it has been severe and prolonged. This is, however, rather unusual. The affection is relatively more common among women than among men, and among the well-to-do rather than the poorer classes. It is not infrequently found in several members of the same family, and it may be an inherited peculiarity. It is often bilateral, the second foot becoming affected usually after a considerable interval. The affection is usually chronic in character and not infrequently the patients are of a nervous or possibly neurasthenic type.

As has been stated, pain, although far more common at the fourth articulation, is by no means confined to this point. In some instances the patient is unable to localize the pain accurately, in others it is referred to the three adjoining toes, second, third, and fourth. In certain cases the greatest complaint is of sensitiveness of the metatarso-phalangeal joints to pressure, either direct or lateral. This complaint is more common when the arch is depressed and fixed in this attitude corresponding to the rigid weak foot. In other instances a painful callus beneath the second or third metatarsal head is the source of discomfort.

It should be stated that typical cases of Morton's neuralgia may be present although the foot is apparently normal in appearance.

Etiology.—As has been stated, the attacks of pain, although favored by "hot pavements," by "the sticking of a damp stocking to the foot," by thin soles, by sudden and unguarded movements, and the like, are practically always induced by the shoe, and it may be assumed that the pressure of the shoe upon a weakened and sensitive part induces the cramp. The influence of the shoe, as the author has suggested elsewhere (New York *Medical Record*, August 6th, 1898) may be explained as follows. Normally, lateral pressure on the hand or foot compresses it and increases the depth of the arch, as the tight glove does the hand. If, however, this increase of the arch is prevented, the adjoining bones cannot escape direct lateral pressure, a pressure that then becomes extremely painful, as one may demonstrate upon one's self by squeezing the hand suddenly while the metacarpal bones are fixed in the same plane; or if one finger of the hand be dorsiflexed so that the metacarpo-phalangeal joint is forced below the level of its fellows, pain on lateral pressure is always referred to this point. The same manœuvre causes pain in the foot at the corresponding articulation. It is evident also that in the foot an articulation that is depressed habitually will be constantly subjected to greater weight, or direct pressure as well, when it is in use.

Of all the causes of weakness and deformity of the anterior part of the foot the shoe is by far the most important. The lateral compression of the narrow and ill-shaped sole induces distortion of the toes and atrophy of the muscles that have lost their function. Thus the fore foot, deprived of its accessory supports, is subjected to abnormal pressure. The depression of the metatarsal arch is induced by the persistent dorsiflexion of the toes which is the attitude of shoe-wearing people, an attitude favored by direct compression by the rocker shape of the

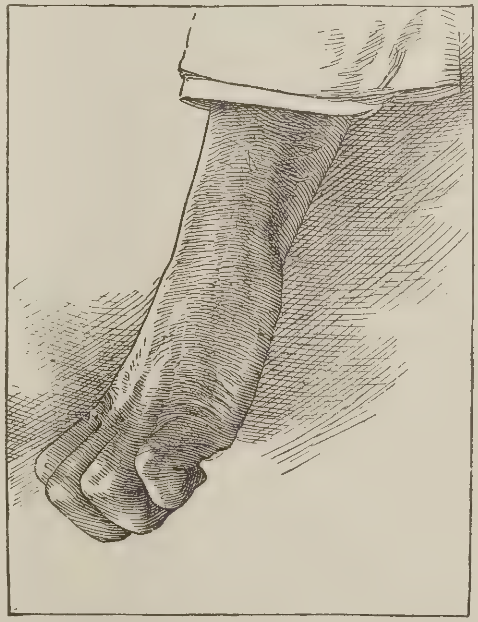


FIG. 2141.—An Attitude in which Lateral Pressure is Painful.

ordinary shoe and by the slight depression of the sole beneath its centre.

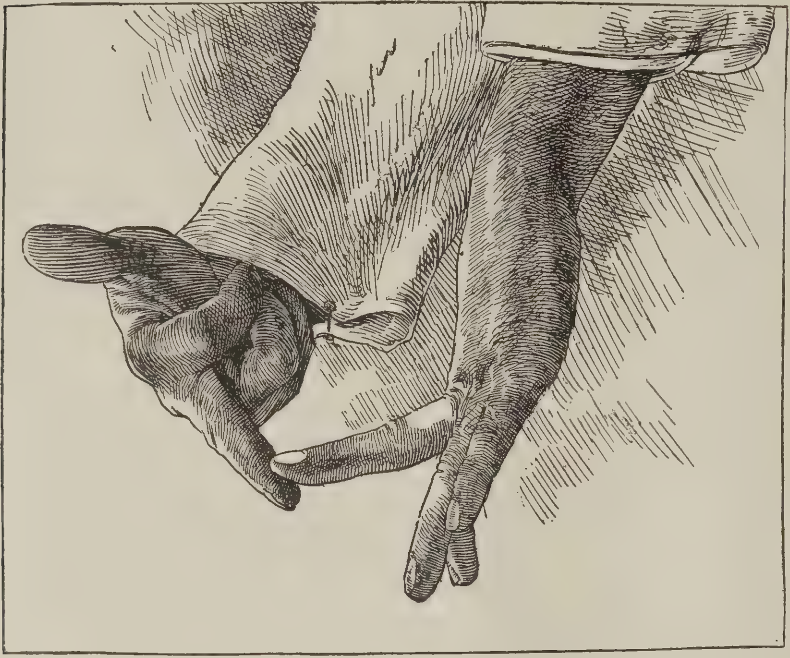


FIG. 2142.—In this Attitude Lateral Pressure Causes Pain at the Depressed Joint.

In the depressed arch, that metatarso-phalangeal joint that is lowest is subjected to abnormal pressure and it is liable to lateral compression as well, the latter being the direct cause of the characteristic cramp. The fourth articulation is that most liable to injury because it is practically the outer support of the arch, as the fifth joint is almost always on a higher plane or in an attitude that favors injurious pressure.

This may be readily illustrated by the school boy trick of suddenly compressing the hand when the fifth metacarpal bone is above the level of the fourth.

In many instances of Morton's cramp there seems to be simply a laxity of tissues that allows a sudden displacement downward of the fourth articulation or elevation of the fifth, a movement as of something slipping in the bone which is followed by the characteristic pain. This displacement may be induced by a misstep or by overexertion and not infrequently the first appearance of the affection dates from a sprain or twist of the foot, or is induced by extreme dorsiflexion of the toes. It may be stated also that extreme dorsiflexion may cause a subluxation of one of the joints which in itself may be the cause of the peculiar pain. There are, of course, other predisposing or exciting causes of this pain than the simple local causes that have been mentioned: for example, weakness of the longitudinal arch, the hollow foot, in which the plantar fascia is contracted; gout, rheumatism, or other local or constitutional affection that may make the foot abnormally sensitive.

Pathology.—It would appear, as has been stated, that the ordinary cause of the symptoms is pressure, which, as the attacks recur, makes the articulation in general sensitive. The more intense pain is due apparently to injury and pressure on the digital nerve and in certain instances a local neuritis may be present. Other changes in and about the joint are usually those secondary to the abnormal position of the part.

Treatment.—The treatment should be conducted with the aim of removing the direct causes of the discomfort and of restoring the normal condition of the weakened part. The first essential is therefore to provide the patient with a proper shoe. This must correspond with the outline of an undistorted foot; the sole should be thick and the shank should be arched to give proper support to the sole. A laced shoe that may be drawn tight about the arch usually adds to the comfort of the patient. The sole should be flat and it should be somewhat thicker in the centre so that it may form a slight convexity beneath the metatarsal arch. In fact the object of mechanical treatment is to support this anterior arch in its proper position. For this reason it is well in most instances to provide the patient with a light steel sole plate, fashioned on a plaster cast of the sole of the foot, of which the longitudinal and anterior arches have been somewhat exaggerated. This plate, as is shown in the diagram, usually extends from the centre of the heel to slightly beyond the metatarso-phalangeal joints, but in certain instances it is of advantage to extend it farther forward in order to splint the foot and prevent dorsal flexion of the toes if this motion induces discomfort or if the part is especially sensitive. As an immediate treatment the fore foot from the tarsus to the phalanges may be bound by strips of adhesive plaster, the metatarsal region being compressed somewhat as a tight glove compresses the hand; the elevation of the arch may be further assured by inserting a pad of felt or leather beneath it. This is a very effective means of relieving the discomfort and preventing the recurrent cramp.

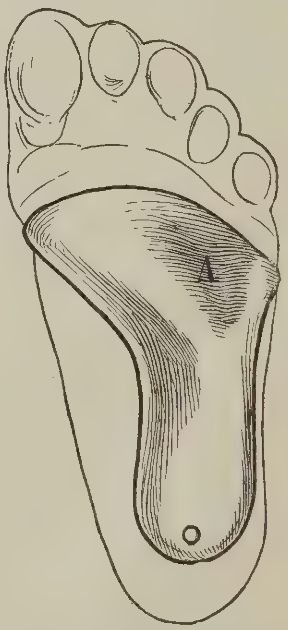


FIG. 2143.—A Brace to Support the Anterior Arch. *A*, The point of greatest elevation beneath the painful part.

In acute cases or when the part is very sensitive, and particularly in those cases that have resulted directly from injury, a plaster bandage may be applied, the foot being fixed in an attitude of slight dorsiflexion and adduction. The metatarsal arch should be exaggerated and the toes fixed in slight plantar flexion. If the arch is rigidly depressed, as in certain cases complicated by rheumatism and the like, the deformity must be overcome by forcible manipulation under anæsthesia before the bandage is applied.

In all cases the patient should endeavor, in the after-treatment, to regain the power of plantar flexion of the toes by manipulation and by exercise, and by pressing the toes firmly against the sole of the shoe to assist, as far as may be, the weakened arch in the performance of its labor.

Operative Treatment.—An effective treatment, and one that may be necessary in the persistent type of this affection, is excision of the head of the metatarsal bones, if, as is usual, the pain is localized at this point. This operation, the treatment of routine suggested by Morton, is easy of performance and it usually affords relief. The resulting deformity is but slight. In most instances it is, however, unnecessary.

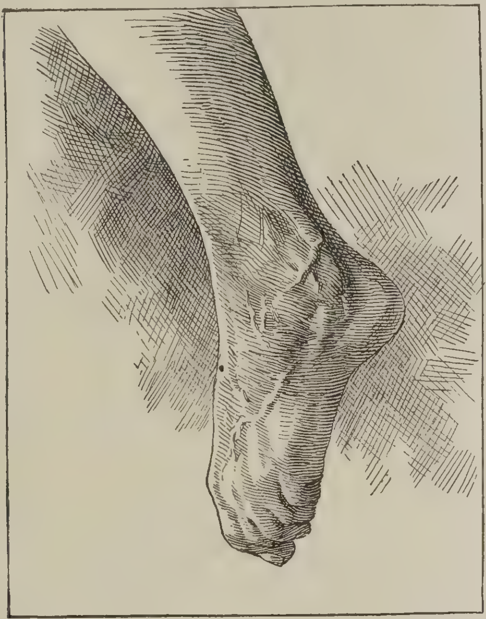


FIG. 2144.—Plantar Flexion of the Toes. An exercise for strengthening the anterior arch and overcoming deformity.

Depression or contraction of the longitudinal arch, which in certain instances may predispose to the discomfort, should be relieved if possible.

Massage, the hot-air bath, the application of various liniments are of some service in certain cases as adjuncts. Constitutional treatment is also indicated in those cases in which there is a gouty or rheumatic tendency or other complication.

V. HALLUX RIGIDUS. (Synonym: Hallux flexus.) Hallux rigidus is a painful affection of the great toe joint accompanied by restriction of motion. In well-marked cases the toe may be habitually plantar-flexed to a slight degree; hence the name hallux flexus suggested by Davies-Colley. In this class the motion may be much restricted, particularly in dorsal flexion, thus interfering with proper functional use of the foot. There is usually pain of a burning, throbbing character referred to the joint and increased by use, and a certain degree of congestion is often present.

Etiology.—Hallux rigidus is usually seen in adolescence as a complication of a weak arch which allows the fore foot to be crowded into the narrow part of the shoe, thus subjecting the great toe joint to lateral and longitudinal pressure. In some instances the habitual flexion is the effect of an instinctive effort of the patient to support a weakened arch by downward pressure of the great toe. (Hammer-toe flat foot. Nicoladoni.)

The affection may also be induced directly by injury, as by stubbing the toe or by kicking a hard object, or it may be a complication of rheumatism or gout.

There are no distinctive changes in the joint other than those secondary to long-standing restriction of function and deformity.

Treatment.—If the rigid joint is a secondary effect, as in most instances it is, of the weak or broken-down foot the first step is the treatment of the exciting cause (see Weak Foot). In any event a properly fitting shoe must be worn, which exerts no pressure on the sensitive part. The sole must be thick, so that movement in the joint may be restricted, and in certain instances it may be necessary to insert a steel brace between the layers of the sole of the shoe in order to prevent all motion for a time. If direct pressure on the toe joint causes discomfort, the sole of the shoe may be made very thick just behind the sensitive part, so that the weight is supported as it were on an anterior heel (Fig. 2145).

If the affection of the toe complicates a rigid flat foot, as is not infrequently the case, the deformities should be over-corrected under anæsthesia (the flexed toe being forcibly extended), and fixed in a plaster bandage in the manner described in the section on Weak Foot. In extreme, and very exceptional, cases of long standing, excision of the joint may be required.

VI. PAINFUL GREAT TOE. Pain, on motion and pressure, at the great toe joint, and symptoms resembling those of hallux rigidus, are not uncommon in older subjects. These symptoms are induced usually by a long walk or by strain or other injury.

The treatment is based upon essentially the same principles as those governing the treatment of the former affection. Thus, for example, splinting may be employed, when necessary, to restrain painful motion, and a proper shoe may be fitted for the relief of pressure.

Pain about the great toe is a common symptom of the weak arch, or of the contracted foot. It may be caused simply by the pressure of a tight shoe. It is often present as a symptom of hallux valgus and of its accompanying bunion. The joint may be directly involved in gout, rheumatism, and the like. The treatment must be directed to the cause.

VII. HALLUX VALGUS. Hallux valgus is a deformity of the foot, in which the first metatarsal bone is adducted and at its anterior extremity separated from its fellows, while the toe is turned outward or abducted to a greater or less degree. Thus although the area of the toes is contracted the fore foot is actually broadened.

In consequence of the distortion there is an actual displacement of the joint surfaces. In marked cases, the first phalanx of the distorted toe articulates only with the external condyle of the metatarsal bone, while the internal condyle, projecting on the inner side of the foot, is subjected to the direct pressure of the shoe. Here a bursa forms and this is in turn surmounted by a corn or callus.

The projecting condyle, sometimes irregular and hypertrophied by the deposit of periosteal bone, the bursa, and the overlying corn make up the enlarged joint or so-called bunion. In cases of this type there is usually more or less abduction of the other toes, and the great toe, often rotated on its long axis, may be displaced above or below its fellows.

Etiology.—By far the most important of the predisposing and exciting causes of the deformity, and of the consequent pain and discomfort, is the shoe. In fact a moderate degree of hallux valgus, shown by the projecting "enlarged" joint, is so common as to pass as the normal condition of shoe-wearing people. The influence of the shoe is increased when the longitudinal arch is weak, as the parts are then subjected to greater pressure. The deformity, or more especially the symptoms, may be increased by gout, rheumatoid arthritis, and the like, and by overstrain and injury as well.

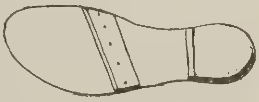


FIG. 2145.—The Anterior Heel.

Pathology.—The pathology does not call for extended comment. There are the usual changes in and about the joint that accompany similar subluxations, the cartilage disappears from the exposed parts of the internal condyle, and the ligaments and the muscles contract on the shortened side and oppose the rectification of the deformity.

Symptoms.—The most important sign of hallux valgus is the deformity. The most important symptoms are the pain and sensitiveness induced by the pressure upon the projecting joint. The discomfort is, of course, greatly increased by the inflamed bunion and accompanying corn. There may be pain also beneath and about the joint. Pain in the joint may be in part symptomatic of the irritation and changes secondary to the deformity itself. Pain beneath the joint is usually caused by the greater pressure to which the part is subjected by the outward rotation of the foot, an attitude that is almost always assumed by the patient if there be an accompanying weak foot. In certain instances pain beneath the joint may be due to irritation about one of the displaced sesamoid bones which are sometimes adherent and are sensitive to direct pressure.

Treatment.—In the slighter degrees of deformity the symptoms may be checked by the use of a proper shoe, straight on the inner side and with capacious upper leather. This removes the direct pressure and allows an opportunity for normal movement. Making the sole somewhat thicker on the inner border is of advantage also, as it inclines the weight slightly toward the outer part of the foot. In addition, daily manual correction of deformity, together with alternate voluntary flexion and extension of the toe while it is guided by the fingers in the normal direction, is of advantage from the curative standpoint.

A number of appliances have been devised to hold the toe in normal position while the foot is in use. In most instances, however, the incidental discomfort is sufficient to prevent their use. One of the simplest and most efficient of these devices is the Holden toe post, a thin upright of metal fixed in the front of the sole of the shoe, making a compartment into which the toe is guided and thus held in an improved position. This toe post necessitates a digitated stocking and a special shoe; like other appliances it is very uncomfortable unless it is perfectly adjusted, and until the patient has become accustomed to it.

It must be borne in mind that a part of the deformity of hallux valgus is caused by the adduction of the metatarsal bone. It is well, therefore, to lessen this displacement by the use of a bandage or by adhesive-plaster strapping about the fore foot, so applied as to exercise a certain amount of compression at this point.

It has been stated also that weakness of the arch or flat foot is a common accompaniment of hallux valgus. In such cases a proper support is an essential part of the treatment.

As a rule patients demand treatment rather because of the discomfort than because of the slight degree of deformity. This discomfort is due to the pressure on the sensitive bunion lying on the projecting condyle, and the removal of this projecting bone will practically relieve the symptoms.

A simple and effective operation is conducted as follows. A slightly curved incision is made below the joint, the bunion is dissected from the adherent skin, the joint is opened and the projecting bone, usually the greater part of the internal condyle of the metatarsal bone, smoothly removed with a chisel, after which the capsule is closed with fine catgut as in the external wound. The toe is then straightened by stretching the contracted tissues. The entire foot is slightly adducted, or turned inward, and together with the leg is enclosed in the plaster, the toe being fixed in the corrected position by the same means.

As soon as the weight can be supported without discomfort the patient is allowed to walk about on the foot. Afterward, manipulation, exercises, the use of a proper shoe together with a flat-foot brace, if this is indicated, will complete a practical cure.

Modifications of the Operation.—In certain instances there may be contraction of the extensor tendon of the toe. Weir has suggested that this may be divided and sewed to the periosteum on the outer border of the first phalanx, thus serving to prevent recurrence of deformity.

In more extreme cases of contraction and deformity, resection of the head of the metatarsal bone may be indicated. Cuneiform osteotomy of the metatarsal bone has been suggested, but this, to be effective, must include the projecting condyle.

Fowler's Operation.—In this procedure the incision is made between the first and second toes, the ligament is divided, and the toe is displaced inward. The bunion and the projecting portion of the internal condyle are then removed if necessary, the toe is replaced, and the wound closed. This operation appears to offer no advantage over the simple one that has been described, for, when properly performed, the scar is insignificant and is not subjected to pressure if it be made slightly below the most prominent part of the joint.

Bunion.—The treatment of the bunion, the inflamed sac and corn, may be summarized as rest with hot or cold applications during the active stage, with relief of pressure by the use of a proper shoe. In many instances a metallic support for the arch to remove the direct pressure on the toe is indicated. Operations should as a rule be deferred until the acute symptoms have subsided. An effective operation must include the removal of the projecting bone as well as the sac.

VIII. HALLUX VARUS AND PIGEON TOE. The term hallux varus is properly applied only to persistent adduction of the great toe, while pigeon toe is the popular name for in-toeing, an attitude usually caused by an inward rotation of the entire limb.

Hallux varus is usually congenital; the great toe turns inward, sometimes when in active motion, to a marked degree, in fact it may be almost prehensile in its movements.

In certain instances there is slight accompanying adduction of the foot at the medio-tarsal joint, constituting a mild degree of talipes varus. The mother's attention is usually attracted to the condition, not by an actual deformity of the toe, but by difficulty in putting on the baby's stocking.

Hallux varus is occasionally seen also as an acquired peculiarity in connection with certain varieties of weak foot (valgus). In such cases there is a marked inward bulging at the medio-tarsal joint which is compensated for by an exaggerated inward twist of the fore foot and adduction of the great toe (Fig. 2130).

Treatment.—Simple hallux varus, as a rule, requires no treatment since it is cured by the use of the shoe when the child begins to walk. In more extreme cases the prehensile movements may be restrained by a narrow band of adhesive plaster passed over the toes and fore foot. If talipes varus is present it should be treated in the ordinary manner (see Talipes).

PIGEON TOE.—Hallux varus is a rather unusual cause of the in-toeing gait, or so-called pigeon toe, which, as has been stated, is caused as a rule by inward rotation of the entire limb rather than by a deformity of the toe or foot. This rotation of the limb may be caused also by bow legs in which there is an accompanying inward twist of the tibiæ and occasionally it may be induced by a restriction of the range of outward rotation at the hip joints.

As a rule, however, pigeon toe is a compensatory attitude symptomatic either of weak feet or of knock knees, and it is therefore far more often a secondary than a primary attitude. The proper position of the feet in walking, at least in childhood, is one of parallelism. In fact the exaggerated outward rotation of the feet which is so commonly seen, is more abnormal than a slight degree of in-toeing. As the latter attitude, from the conventional standpoint, passes for deformity it usually attracts the mother's attention before the weakness, of which it is so often a symptom.

Treatment.—The rational treatment must be directed to the cause of the peculiar attitude, viz., the bow leg, the knock knee, or the weak foot. In many instances the in-toeing habit remains for a time, after the removal of its cause, and systematic training in walking with the feet rotated outward may be necessary to overcome it.

If there be actual limitation of the range of outward rotation at the hip joints, as is sometimes the case, this must be overcome by systematic stretching.

In the absence of knock knee or weakness of the arch the tendency to in-toeing may be lessened by making the sole of the shoe somewhat thicker on the outer border.

In the more exaggerated types, the use of elastic tapes attached to the front and outer margin of the soles of the shoe, passing about the back of the leg from without inward over the front of the thigh and across the buttock, to be attached to the middle of the waist band, is an efficient treatment.

IX. Hammer Toe. Hammer toe is a persistent flexion of a toe, usually of the second. In well-marked cases the first phalanx is dorsiflexed, the second plantar-flexed, and the third may be flexed and extended. The toe is usually compressed between its fellows, while its extremity, lying on a lower level, is flattened out against the sole of the shoe into a club or hammer shape. On the dorsal surface of the flexed joint which is subjected to pressure from above there is usually a sensitive corn or callus. The discomfort of the hammer toe is caused by the pressure of the shoe upon the corn above and upon the hypertrophied extremity below, of which the nail is not infrequently ingrown.

Etiology.—Hammer toe may be congenital, but in the great majority of cases it is an acquired deformity caused by narrow and short shoes. The second toe is more often involved because it is the longest and is subjected to greatest lateral pressure also. In cases of long standing all the tissues are shortened on the plantar or short surface, the most resistant contraction being in the ligaments of the first phalangeal joint.

Treatment.—Congenital hammer toe may be corrected in infancy by manipulation and by retention with a strip of adhesive plaster. The slight degrees of hammer toe in older subjects may be treated in a similar manner by methodical stretching and splinting with some light material such as celluloid. In such cases a digitated stocking is of advantage. In all cases a wide, capacious shoe which exerts no pressure whatever, is the first essential.

Confirmed hammer toe may be treated by division of the resistant parts, particularly of the ligaments of the first interphalangeal joint, and by correction followed by retention for a time with a digital splint of elastic material or a leather inner sole. In most instances, however, patients demand treatment for the relief of the discomfort caused by vertical pressure upon the flexed toe, rather than for the absolute restoration of symmetry. For this class the most efficient procedure is resection of the prominent joint, sufficient bone being cut away from the adjoining phalanges to remove the projection completely. By such a procedure permanent relief may be secured.

X. Overlapping Toes. Irregularity in the line of the toes is sometimes observed in infancy; for example, a congenital hammer toe may be present or the little toe may be set upon a higher level than its fellows.

The irregularities may be treated by methodical manipulation and by retention of the distorted member by straps of adhesive plaster passed above and beneath it, fixing it to its fellows. Irregularities of this character in older subjects are almost always caused by improper foot wear, with the exception of distortions caused by rheumatism or by lesions of the nervous system, and the like. In this class, the use of a proper shoe will usually relieve the symptoms.

XI. Achillo-Bursitis. (Synonym: Achillodynia.) In 1893 Albert* suggested the title Achillodynia to characterize a group of symptoms caused, in most instances, by irritation or inflammation of the bursa lying between the tendo Achillis and the posterior surface of the os calcis.

Etiology.—In certain cases the bursitis may be caused directly by pressure, injury, or overstrain, but in many instances rheumatism, gout, gonorrhœa, and the like, appear to be predisposing or exciting causes of this, as of similar affections of bursæ and tendon sheaths elsewhere. Concretions within the bursa or exostoses beneath it may be mentioned as possible causes, or complications.

Pathology.—In chronic cases the bursa is thickened and enlarged and the lining membrane is fringed and reduplicated. The contents may be serous or semisolid and concretions may be present. Suppuration may occur within the sac or it may be the seat of syphilitic or tuberculous disease. The periosteum in the neighborhood is usually thickened, and the underlying bone may be congested and softened.

Symptoms.—In typical cases there is sensitiveness to pressure over the back of the heel, and pain or discomfort exaggerated by functional use, particularly by motions and attitudes that increase the strain upon the tendon. The pain may radiate up the leg or it may be referred to the bottom of the heel. Patients often complain also of a sensation of laxity and insecurity in the subastragaloid articulation. In a large proportion of the cases the symptoms of the weak foot accompany or follow those of achillodynia. In the latter instance this is explained doubtless by the fact that the loss of the leverage function of the calf muscle induces an awkward gait with a strong inclination toward pronation of the foot, an attitude that throws an increased strain upon its inner border and upon the longitudinal arch. In cases of long standing there is marked atrophy of the calf due to disuse of function and in many instances a broadening of the posterior part of the heel caused by the infiltration or irritation of the periosteum about the insertion of the tendon. The enlarged bursa is usually demonstrable on inspection and palpation. The affection may be unilateral or bilateral, the latter being more common in chronic cases. As a rule the symptoms begin in one foot, the second becoming involved after an interval of several months.

When the symptoms have persisted for any length of time, there appears to be little tendency toward spontaneous recovery, a fact that is explained by difficulty in securing relief from pressure and strain in this situation.

Treatment.—In acute cases, particularly those that have followed injury, the treatment should be—functional rest combined with the application of heat or cold, as may be indicated. When the immediate symptoms have subsided the part may be supported by adhesive plaster so arranged as to relieve the strain upon the sensitive part. A long band of plaster about two and a half inches wide is closely applied to the sole of the foot and calf of the leg, reaching from the toes nearly to the knee, with the foot in slight plantar flexion. This is supported by additional straps about the fore foot and leg, the ankle and heel being completely covered with narrow strips; a bandage is then applied. By this means the direct pull of the muscle on the sensitive part is checked and compression is exerted upon the bursa. The dressing should be renewed when its efficiency is lessened.

If more complete fixation is indicated by the symptoms a light plaster bandage may be applied to hold the foot at a right angle with the leg and slightly adducted. The patient can then use the foot without discomfort. In many instances the application of the cautery seems to hasten the absorption of the effusion. If relief from

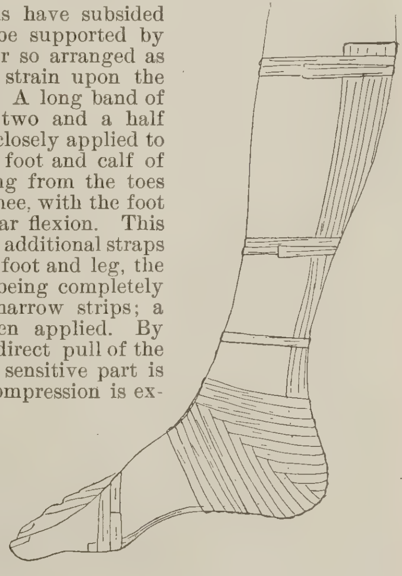


Fig. 2146.—The Manner of Applying Adhesive Plaster.

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* Wien. med. Presse, January 8th, 1893.

function is necessary for any length of time, as in the chronic cases, it is well to apply a leg brace to the shoe with a joint at the ankle so arranged as to prevent dorsal flexion beyond a right angle. As patients are usually sensitive to direct jar, a rubber heel should be employed, and an increased height of the heel sufficient to throw the weight forward upon the front of the foot usually lessens the discomfort.

As has been stated, in the chronic cases there is usually an accompanying weakness of the longitudinal arch. This may require the application of a support and further treatment as described in the section on the weak foot.

Operative Treatment.—In persistent cases, particularly those in which the bursa is palpable and in which the adjoining tissues of the os calcis are infiltrated, the removal of the bursa is indicated. This is accomplished by an incision beside the insertion of the tendon where the bursa is most prominent. Irregularities of the underlying bone should be removed at the same time. The wound is then closed and a plaster bandage is applied. This should be worn until the patient can walk without discomfort. Support may or may not be required in the after-treatment. Operative intervention is of course indicated when suppuration of the sac is present or when it is the seat of primary or secondary tuberculous disease. As has been stated, the local disability may be induced or prolonged by systemic disease. In such instances appropriate remedies should be employed.

XII. Achillo-Bursitis Posterior.—A small sensitive bursa over the insertion of the tendon, between it and the skin, sometimes causes symptoms resembling those of the preceding affection. This bursa is usually caused by the pressure of the shoe, and it may be relieved by removing the exciting cause and by strapping with adhesive plaster.

Bursæ or sensitive points elsewhere on the heel are to be treated in a similar manner. Irregular projections on the bone may require removal.

XIII. Strain of the Tendo Achillis.—Pain on use of the foot referred to the tendo Achillis may follow strain or overuse, the symptoms may resemble those of Achillo-bursitis, but the sensitive point is often localized at the middle of the tendon or at the junction with the muscular substance. Apparently there is, in these cases, an irritation within the fibrous sheath of the tendon or injury to the muscular fibres.

The treatment is functional rest. As a rule the application of the adhesive-plaster strapping, as described in the treatment of Achillo-bursitis, is effective.

XIV. Painful Heel — Calcaneo-Bursitis.—Pain and sensitiveness to pressure referred to the bottom of the heel are common symptoms of the contracted or hollow foot, in which there is abnormal pressure on the anterior and posterior pillars of the arch. It may be in normal feet a symptom of overuse, as when the tissues beneath the heel become sensitive after long standing or walking, and it is a common symptom of the weak foot of which the so-called heel walk is characteristic.

In rare instances the point of tenderness is distinctly localized and is due to a small inflamed bursa lying over the periosteum of the inner tuberosity of the os calcis.

Treatment.—This must be directed to the condition of which the pain is a symptom. The treatment of the weak foot and of the contracted foot is described elsewhere. If the sensitiveness is due to overuse or to abnormal pressure, the use of a rubber heel combined with frequent change from the passive attitude, in which the weight is supported entirely on the sensitive part, may relieve the symptoms. In many instances the use of an arched foot plate, to distribute the pressure along the entire sole, is of service.

Painful bursæ may be protected from direct pressure or removed if necessary. *Royal Whitman.*

FOOT, DISTORTIONS OF.—Talipes.—In the preceding article, the disabilities of the foot of which the discomfort is of greater importance than the deformity have been described. One may now consider those of congenital and acquired origin of which deformity is the most noticeable feature. A distortion of the foot of this class is simply an abnormal retention of a normal attitude, or what is an exaggeration of a normal attitude. In other words the centres of motion, at which the foot is deformed, are the centres of normal motion and the different distortions may be simulated by a normal subject. If the foot has been fixed in the abnormal attitude during fœtal life, or if it has been used for any length of time in the abnormal position, the deformity becomes exaggerated beyond the possibility of imitation, and secondary variations in its shape, size, and nutrition follow.

The deformities of the foot are grouped under the generic name talipes, derived from talus (ankle) and pes (foot), signifying therefore a form of deformity in which the patient walks upon his ankles. Talipes was therefore originally synonymous with the popular term club foot, but at the present time it is used preferably as a prefix to the descriptive titles of the different distortions, while club foot is usually applied only to the most common of the deformities, equino-varus, in which the distorted foot is club-like in form.

Varieties.—There are four *simple* varieties of the distorted foot or talipes:

1. *Talipes Equinus*, the extended or plantar-flexed foot. In well-marked cases the patient walks upon the heads of the metatarsal bone, an attitude that suggested the name equinus (horse-like).

2. *Talipes Calcaneus*, the dorsi-flexed foot in which the heel is prominent, and which alone bears the weight in walking; hence, calcaneus from calcaneum, the heel bone.

In these forms the centre of motion is at the ankle joint. Under the terms equinus and calcaneus are included not only the cases of marked deformity, but also those in which the range of dorsal or plantar flexion is sufficiently limited to cause a change in the contour of the foot.

3. *Talipes Varus*, the inverted foot. In this deformity the foot is turned in or adducted, and combined with the inward twist, which exaggerates the normal curve of the inner border, there is always a certain amount of supination, or inversion; that is, the inner border of the sole is elevated and the outer border is depressed, so that the weight falls to the outer side of the centre of the foot.

4. *Talipes Valgus*, the everted foot. This deformity is the reverse of varus. The foot is abducted, that is, the foot is twisted outward at the centre and pronated, so that in use the weight falls on the inner border.

In these forms of lateral deformity the centres of motion are at the mediotarsal and subastragaloid joints.

These simple deformities in which the foot is persistently extended or flexed, or twisted in or out, are comparatively uncommon.

Compound Deformities.—As a rule, the deformities are combined in varying degree; thus, the over-extended or the over-flexed foot is usually twisted inward or outward, making four varieties of compound deformity. 1. *Talipes equino-varus*—downward and inward. 2. *Talipes equino-valgus*—downward and outward. 3. *Talipes calcaneo-varus*—upward and inward. 4. *Talipes calcaneo-valgus*—upward and outward.

In the simple and compound varieties of talipes the arch of the foot may be increased or diminished in depth. It is, for example, usually increased in calcaneus and equinus, and it is usually diminished in valgus; but this secondary or subordinate deformity is not recognized in the ordinary classification. If the arch of the foot is exaggerated, the condition is sometimes called *talipes cavus;* if it is lessened or lost, *talipes planus.* These slight degrees of distortion, in which the functional disability is far more important than the deformity, are rarely classed as forms of talipes. Simple cavus, the hollow or contracted foot; and planus, one of the forms of the common weak or flat foot, have been described already.

Etiology.—From the remedial standpoint, the cause of the deformity is of far greater importance than its form. Thus the distortions of the foot fall primarily into two groups: 1. *The congenital form*, in which the foot has become deformed in process of formation. 2. *The acquired form*, in which the foot, perfect at birth, has at a later time become distorted.

Congenital Talipes is simply a twisted foot, of which the component parts, although malformed to a greater or less degree, are capable of regaining perfect form and function. This is practically true of the great majority of cases, although there are exceptional instances in which congenital deformity is complicated by defective formation of the foot or leg, or in which the deformity is caused by, or at least accompanied by, paralysis, as, for example, in certain forms of spina bifida or other congenital defect or disease of the nervous apparatus.

Acquired Talipes is almost always a consequence of paralysis of spinal origin (anterior poliomyelitis) in early childhood. Certain muscles or groups of muscles being paralyzed, the muscular force is unbalanced and the foot is drawn into a distorted position by the action of the unopposed muscles, and by the influence of gravity. This distortion is confirmed and increased by the accommodative changes that accompany functional use and growth in the abnormal attitude.

Far less often acquired talipes may be the result of paralysis of cerebral origin, of other forms of spinal disease, of local paralysis following neuritis or injury to a nerve trunk. It may be caused by scar contraction, as after a severe burn, or by direct injury to the bone, or by disease that may interfere with subsequent growth. Such are, however, extremely uncommon causes, and the statement holds good that congenital talipes is a simple distortion capable of perfect cure, while the acquired talipes is a deformity and disability usually secondary to disease of the spinal cord. It is therefore capable only of rectification, not of perfect cure unless recovery from the original disease, of which it is a result, has taken place.

CONGENITAL TALIPES.

Etiology.—The etiology of congenital talipes as of other congenital deformities is somewhat conjectural. In some instances the influence of inheritance is apparent, and again two or more children with club foot may be born of the same mother, but, as a rule, there is nothing in the family or personal history that can in any manner explain the deformity. The most reasonable explanation applied to the majority of cases is that the foot has from some cause remained for a longer or shorter time in a constrained or fixed position, and has thus grown into deformity.

It has been claimed by Eschricht, and by Berg (Berg, *Archives of Medicine*, New York, December 1st, 1882) that at about the third month of intra-uterine life the thighs of the embryo are abducted, flexed, and rotated outward, the legs are crossed, and the feet are plantar-flexed and adducted so that the inner surfaces of the thighs, the tibial borders of the legs, and the plantar surfaces of the feet are held in close apposition to the abdomen and to the pelvis of the fœtus. Later there is an inward rotation of the legs so that the feet are turned gradually outward until the soles are brought into contact with the uterine wall, the feet then being in the attitude of abduction and dorsal flexion. According to this theory there is a regular succession of attitudes during intra-uterine life. If the inward rotation of the lower extremity is prevented, or if it is incomplete, the foot remaining in the original position becomes deformed. Thus, equinovarus being the normal attitude of the early and middle period of intra-uterine life, is the most common and the most intractable of the congenital deformities. If the constraint or pressure is not exerted until a later period, after rotation has taken place, when the foot has attained or nearly attained its normal size and shape, it will then induce the less common and comparatively slight grades of deformity such as calcaneus or valgus.

This theory which seems interesting and reasonable, appears to rest on an insecure basis. Bessel Hagen states that in embryos of 30 mm. in length, the foot is in extreme plantar flexion; in those of 90 to 100 mm., the foot is at a right angle to the leg; and from this size to that at full term, the foot may be found in any position, abducted, adducted, or dorsiflexed. He states also that supination is not the usual attitude at an early period, but is more common near the termination of intra-uterine life, and that when it is present it is more often combined with dorsiflexion. In other words, there is no time when the foot regularly and normally assumes the attitude of club foot, from which it is changed by the rotation of the legs. Scudder (*Boston Medical and Surgical Journal*, October 27th, 1887), after similar investigations, arrived at practically the same conclusions. He states that there is no necessary relation between the age, the rotation of the legs, and the position of the feet.

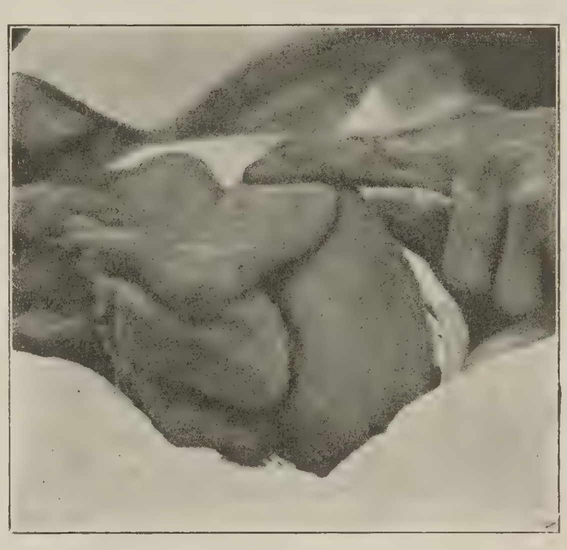

Fig. 2147.—Congenital Talipes Illustrating the Attitude of the Limbs at Birth.

It would appear, however, that there is during the process of development a normal alternation of attitudes and postures. If the feet for any reason are fixed in one position during this period of rapid growth, distortion must follow; if the constraint is slight, and if its influence is exerted at a late period, the deformity will be slight; if it occurs at an early period, the deformity will be more resistant.

One of the causes of constraint, and thus of ultimate deformity, appears to be the interlocking of the feet. Many museum specimens show this, and in some of the cases of talipes seen during the first weeks of life, the feet may be replaced in the attitude in which they had been fixed before birth. Intra-uterine pressure, although not necessarily direct pressure, undoubtedly has an influence in aggravating the deformity. The effect of pressure is not infrequently shown in atrophic areas of skin, and bursæ even are sometimes found over prominent bones. Entanglement in the umbilical cord, the direct pressure of extra- or intra-uterine tumors, and the like, may be mentioned also as possible causes of restraint or fixation of the foot that induces deformity. Further evidence of restraint of normal movements and of abnormal attitudes of the limbs is seen not infrequently in connection with club foot. For example, there may be hyperextension or fixed flexion of the knees, and in cases of extreme deformity the foot is often smaller than normal or otherwise asymmetrical. In certain instances the distorted foot may be imperfect in structure; toes may be absent ("spontaneous amputation"), or constricting bands about the leg or foot may be present. Such abnormalities are usually ascribed to amniotic adhesions. Talipes may be combined with evidences of impaired or arrested development, with harelip, exstrophy of the bladder, spina bifida, absence of patellæ, or with other deformities, such as club hand and wry neck. Or there may be evidence of intra-uterine disease, as shown by ankylosis of joints or by so-called fœtal rickets. Finally, deformities of the foot may be complicated by absence of bones of the foot or of the leg, indicating original defects in the germ itself. This latter group, which includes the complications of club foot and imperfection of structure, is comparatively small. As has been stated, congenital club foot, in the great majority of cases, is a simple deformity capable of perfect cure.

The relative frequency of the congenital and acquired forms of talipes has given rise to much discussion in the past, and statistics on this point are at considerable variance with one another. This may be explained by the fact that acquired paralytic talipes is, as a rule, a preventable deformity. At the present time the extreme degrees of acquired talipes are comparatively infrequent and the deformity is usually of a much slighter grade than the corresponding form of congenital distortion.

SEX OF CONGENITAL TALIPES.*

Males.	Females.	Total.
1,066	585	1,651
64.5%	35.5%	

SEX OF ACQUIRED TALIPES.

Males.	Females.	Total.
975	828	1,794
54%	46%	

Congenital talipes is much more common among males than among females. All the statistics are in accord upon this point. Acquired talipes is more equally divided between the sexes.

FOOT AFFECTED IN CONGENITAL TALIPES.

Right.	Left.	Both.	Total.
510	440	710	1,660
31.1%	26.8%	42.7%	

Unilateral...	950	57.2%
Bilateral.....	710	42.7%

FOOT AFFECTED IN ACQUIRED TALIPES.

Right.	Left.	Both.	Total.
781	768	254	1,803
43.3%	42.6%	14.1%	

Unilateral...	1,549	85.9%
Bilateral....	254	14.1%

In congenital talipes the deformity is far more often bilateral than in the acquired form. In each variety the right foot appears to be more often affected than the left.

THE RELATIVE FREQUENCY OF THE DIFFERENT FORMS OF CONGENITAL TALIPES.

	Cases.	Per cent.
Equino-varus	1,272	77.0
Valgus	123	7.4
Varus	85	5.1
Calcaneo-valgus	52	3.1
Equinus	40	2.4
Calcaneus	28	1.7
Equino-valgus	28	1.7
Calcaneo-varus	7	
Cavus	5	
Valgo-cavus	1	
Equino-cavus	1	
Different deformity in each foot	18	
Total	1,660	

RELATIVE FREQUENCY OF THE DIFFERENT FORMS OF ACQUIRED TALIPES TOGETHER WITH THE ETIOLOGY.

	Anterior Poliomyelitis.	Cerebral. Hemiplegia.	Cerebral. Paraplegia.	Other Forms of Paralysis.	Traumatic.	Total.	Per cent.
Equino-varus	479	28	35	4	29	575	32.5
Equinus	321	66	46	3	26	462	26.1
Calcaneus	219	3	1	0	1	224	12.6
Valgus	134	4	7	1	27	173	9.7
Equino-valgus	114	0	5	0	3	122	6.9
Calcaneo-valgus	76	0	0	0	2	78	4.4
Varus	41	2	1	0	5	49	2.7
Calcaneo-cavus	12	0	0	0	0	12	
Equino-cavus	22	0	0	0	2	24	1.3

RELATIVE FREQUENCY OF THE DIFFERENT FORMS OF ACQUIRED TALIPES TOGETHER WITH THE ETIOLOGY.—*Continued.*

	Anterior Poliomyelitis.	Cerebral. Hemiplegia.	Cerebral. Paraplegia.	Other Forms of Paralysis.	Traumatic.	Total.	Per cent.
Calcaneo-varus	11	0	0	0	0	11	
Cavus	35	1	0	0	0	36	2.0
Varo-cavus	1	1	0	0	0	2	
Deformity different on each side	....	....	....	....	....	50	
Total	1,465	105	95	8	95	1,818	

Anterior poliomyelitis 1,465, 82.8 per cent.; cerebral 200, 11.3 per cent.; traumatic 95, 5.3 per cent.

COMPARATIVE FREQUENCY OF THE DIFFERENT FORMS OF TALIPES, CONGENITAL AND ACQUIRED.

	Congenital.	Acquired.
Equino-varus	77.0 per cent.	32.5 per cent.
Valgus	7.4 "	9.7 "
Varus	5.1 "	2.7 "
Calcaneo-valgus	3.1 "	4.4 "
Equinus	2.4 "	26.1 "
Calcaneus	1.7 "	12.6 "

According to these statistics, in three-fourths of the congenital cases the deformity is equino-varus. Equinus and calcaneus, rare as congenital deformities, comprise 38 per cent. of the acquired forms.

Occasionally the deformity of each foot is different, far more often in the acquired than in the congenital form. In 7 of the 18 congenital cases the deformity was equino-varus on one side, calcaneus on the other; in 3 equino-varus and calcaneo-valgus, and in 3 simple varus and valgus. The 50 cases of acquired talipes represented every combination of deformity.

In 31, or 4 per cent., of the 735 cases of congenital talipes, the distortion was combined with other congenital defects or deformities, viz.: In 12 cases with double club hands; in 6 cases with defective development of the hands, webbed fingers, and the like; in 7 cases with spina bifida; in 3 cases with absence of one or more bones of the leg; in 1 case with torticollis; in 1 case with harelip; in 1 case with dislocation of the knee and ankylosis of an elbow; in 2 cases with general rigidity and deformity of the joints.

THE ANATOMY OF CONGENITAL TALIPES EQUINO-VARUS (CLUB FOOT).—Congenital talipes is, in the great majority of cases, the form in which the foot is twisted inward and downward, or in the more extreme cases, inward and upward, and in its club-like appearance justifying the popular name. The ordinary congenital club foot in early infancy is simply a foot held in an attitude of plantar flexion, adduction, and supination. The dorsum of the foot looks forward and slightly outward and

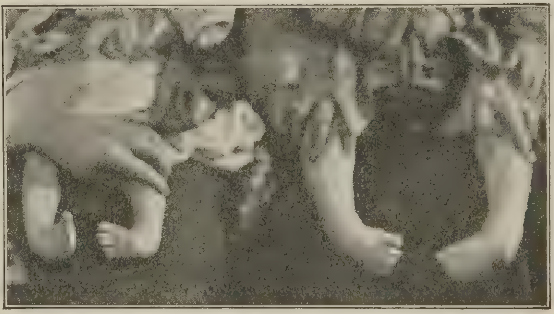

FIG. 2148.—Congenital Club Feet in Sisters, the Twelfth and Thirteenth Children; All the Others Normal.

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* Statistics from Whitman's "Orthopædic Surgery."

upward, the plantar surface is abnormally concave and looks backward, inward, and downward. In many cases the equinous element of the deformity, masked by the extreme inversion of the foot, does not appear until this has been corrected in part. The foot often seems somewhat smaller than normal, and the heel appears to be ill formed. Upon the outer dorsal surface the prominence of the astragalus and os calcis may be felt beneath the skin, the external malleolus is prominent, while the internal malleolus lies deep beneath the redundant tissue of the internal aspect of the foot.

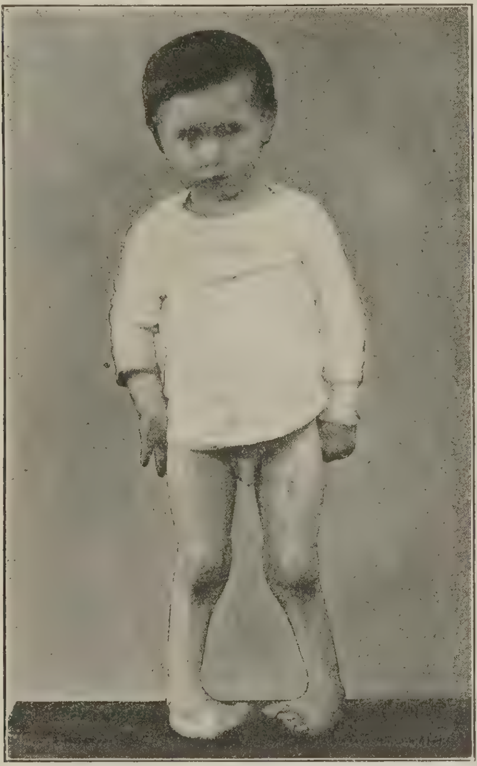

FIG. 2149.—Resistant Club Foot Showing the Secondary Knock Knees.

The internal structure of the foot corresponds to the external contour; thus the relation of the bones to one another, and the shape of the individual bones even, are more or less altered as the deformity is more or less of an exaggeration of the attitudes that the normal foot is capable of assuming. These changes are most marked in the astragalus and os calcis. The astragalus is somewhat wedge-shaped from without inward; it is plantar-flexed so that a large part of its body protrudes from between the malleoli. Its neck is often somewhat longer than normal, and it is, as a rule, depressed and deflected inward. The os calcis is also in an attitude of plantar flexion; the external tuberosity is drawn upward to the vicinity of the external malleolus, its anterior extremity looks downward and inward, and it is often twisted inward on its long axis corresponding to the deformity of the neck of the astragalus. Its external surface looks downward and forward, and it lies directly beneath the astragalus, instead of to its outer side as in the normal relation.

The scaphoid bone is drawn inward and upward, and articulates with the inner part of the deflected head of the astragalus, lying in close proximity to, and often articulating with, the internal malleolus. The cuboid is displaced upward and inward and lies to the inner side of the anterior extremity of the os calcis. The remaining bones are changed in position, but not materially in shape. In many instances the tibia is rotated inward upon the femur at the knee joint, and combined with this inward rotation there may be an inward twist of the tibia on its long axis.

The ligaments are altered to correspond to the changed relations of the bones. Those on the short side are more or less resistant according to the duration of the deformity. The muscles are normal as to their structure and their origin and insertion, but the direction of the tendons as they pass across the foot is changed. Those attached to the inverted side, the extensor and adductor group, are shortened and are relatively stronger than those on the outer side, which are lengthened and atrophied from disuse.

To sum up: all the component parts of the foot participate in the deformity. The most noticeable changes in the bones are in their position and relation to one another, but the astragalus, os calcis, and scaphoid bones are usually somewhat distorted.

The most resistant structures in the deformed foot are the plantar fascia and the ligaments that bind the scaphoid, the os calcis, and the internal malleolus to one another. The muscles that are most active in retaining and increasing the deformity are the tibialis anticus, the tibialis posticus, and the combined gastrocnemius and soleus.

The changes that have been outlined, which are comparatively slight and which may be easily rectified soon after birth, become more marked as the part develops. And when the child begins to walk, the weight of the body, combined with growth and functional use in the abnormal position, increases and fixs the deformity.

In the adolescent or adult type of club foot the deformity may be so extreme that the patient actually appears to walk on the outside of his ankles, as the term talipes implies. The feet turn directly inward, or even inward, upward, and backward, and the peculiar walk, by which interference of inverted feet is prevented, has given another name (reel foot) to the deformity.

Genu valgum is usually present in such cases. This deformity may be congenital, but it is oftener a secondary or accommodative distortion. The legs are shrunken from disuse. The foot itself is atrophied, and is much smaller than the normal. The changes in the bones are much more marked; only a small part of the articulating surface of the astragalus lies between the malleoli, and this posterior extremity is flattened out to the shape of a wedge. There is consequently an apparent backward displacement of the fibula.

All the bones of the foot are more or less atrophied, and the normal area of cartilage has, to a great extent, disappeared from the proper articular surfaces. In this advanced stage the foot serves practically as a simple rigid support.

In these extreme cases cure, in the sense of perfect functional recovery, is of course out of the question; but relief of the deformity, that is, replacement of the foot in the axis of the leg at a right angle to it and in the plantigrade attitude, is nearly always possible.

SYMPTOMS.—The symptoms of congenital club foot are practically included in the description of the deformity. The functional disability is of course considerable, although some patients are surprisingly active and are able to walk long distances. Discomfort from club foot is due almost entirely to the corns or inflamed bursæ over the bony prominences, and its degree depends of course upon the use to which the foot is subjected.

TREATMENT.—Although congenital club foot is an eminently curable deformity, yet perfect and permanent cure often requires minute attention to details during the active stage of treatment, supplemented by long-continued and careful supervision after the cure is supposed to be complete. No other deformity presents such a record of failures and incomplete cures; of relapses after apparent cure; of tedious and ineffective treatment by braces, often for many years, and of unnecessary and mutilating operations. Some of the failures may be explained by the neglect of the parents and by want of opportunity. A few are due to the unusual obstacles in the deformity itself, but by far the greater number must be accounted for by failure of the physician to apprehend the true nature of the deformity, or by his inexperience in the practical details of treatment.

Proper treatment implies suitable opportunity. Under such conditions the treatment of congenital club foot would be included in the first of the following sections:

The infantile club foot is, as has been stated, simply a twisted foot. It is true that there are slight changes in the bones, but the bones of an infant's foot are represented by yielding cartilage which will rapidly reform under changed conditions. The shortening of the muscles and ligaments may be overcome, and when the relation of the bones to one another is set right, the joints will become normal. The treatment of a club foot may then be divided into three stages:

1. The rectification of the external deformity.
2. The support of the foot in proper position during the process of transformation of its internal structure, and until the normal muscular power, unbalanced by the deformity, has been regained.
3. The period of supervision. This would include the treatment of possible complicating deformities of the knee, the laxity of ligaments, and the like, as well as the oversight of the functional use of the foot and the leg during the early years of life.

The First Stage of Treatment: Rectification of Deformity.—It should be stated at once that "rectification of deformity" does not mean apparent symmetry, a misapprehension to which the majority of failures in treatment may be ascribed. It means that when deformity is really rectified all contracted and resistant parts must have been so elongated that every passive motion and attitude possible for the normal foot is equally possible and as easily attained in that which was deformed. This is actual functional rectification, as contrasted with the simple straightening of deformity.

The most important part of the club-foot deformity is varus. The foot that is rolled over and twisted inward to the attitude of extreme adduction, must be untwisted and forced into the attitude of extreme abduction or valgus, the so-called over-correction. Until this is accomplished no attention whatever need be paid to the residual equinus. There are two reasons for dividing the procedure into two parts: first, in order that the attention of the surgeon may be concentrated on one and the most important part of the deformity; second, because by this preliminary untwisting the os calcis is brought into the upright position, into its proper relation to the astragalus, to the bones of the leg and to the tendo Achillis, so that the true degree of equinus may be appreciated.

Preliminary Manipulation. For obvious reasons, the second or third week of life is as early as mechanical treatment can be undertaken. Until then, preliminary manipulation by the nurse, more particularly manual rectification of the deformity by gently drawing the foot toward abduction and retaining it in the improved position for a few minutes, as often as is possible, may be of service in overcoming its resistance. As a treatment by itself, however, simple manual rectification is tedious and ineffective, although partial cures have been attained by perseverance with this means alone.

Mechanical rectification is the treatment of choice and routine in infantile club foot. In this treatment two methods may be described: (1) by the plaster bandage; (2) by some form of simple splint.

The principle of the two is essentially the same. The foot is drawn toward an improved position and retained there by the plaster bandage, or it may be fixed to some form of metal splint or brace whose shape is gradually changed from week to week, as the resistance lessens.

Gradual Rectification of Deformity by Means of the Plaster Bandage.—In this treatment care should be taken to avoid undue pressure, irritation of the skin, or insecurity of the bandage. Shreds of cotton should be placed between the toes, and the outer aspect of the ankle, where the skin is thrown into folds when the foot is straightened, should be smeared with vaseline. A narrow strip of adhesive plaster long enough to reach from the knee to a point an inch or more below the heel is applied to the outer side of the leg. A thin layer of cotton is wound about the leg, just below the knee, in order to protect the skin from the hard margin of the plaster bandage, and a similar strip is carried about the toes. The foot is then drawn gently toward the abducted position, often as far as the axis of the leg at the first dressing, without causing discomfort. While it is held in this position a narrow flannel bandage is smoothly applied to the leg and foot, the band of adhesive plaster being drawn out between the folds about the ankle. A very light plaster bandage is then applied from the knee to the extremities of the toes, and into this bandage the projecting strip of adhesive plaster is incorporated, so that no displacement of the dressing is possible. The turns of both the plaster and the flannel bandage are made from within, downward, and outward, in order that the tension may aid in retaining the foot. When the plaster bandage, which during the hardening process has been constantly rubbed and manipulated so that it may fit the part perfectly, has become firm, a long stocking is drawn over it and is attached to the body clothing. At the end of a week the bandage is removed. The leg and foot are gently bathed with alcohol, thoroughly dried, powdered, and protected as before, and the bandage is again applied. At this second dressing the irritated adductor muscles, after the interval of complete rest, will be much less active and the contracted tissues will be less resistant, so that the foot may be easily turned somewhat outward, or beyond the line of the leg.

After four or five applications of the bandage at weekly intervals the foot, in ordinary cases, can be held without resistance in the attitude of extreme equino-valgus. The sole, which at first looked backward, inward, and upward, is now turned in the opposite direction, forward, outward, and downward, and the inner border of the foot, which was concave, is now convex. When the varus has been completely overcome, treatment is directed to the equinus. At this stage it is sometimes of advantage to cover the bottom of the foot with a plate of thin wood (splint wood or cigar-box cover) to give the plaster bandage more solidity to aid in flattening the rounded sole. At the first application of the dressing one carries the foot upward (toward dorsal flexion), while it is still retained in the abducted position; but when the right-angled position has been attained, it is brought nearer to the axis of the leg. The pronation or eversion of the sole is retained, however, until correction is completed. In correcting the equinus, a certain amount of

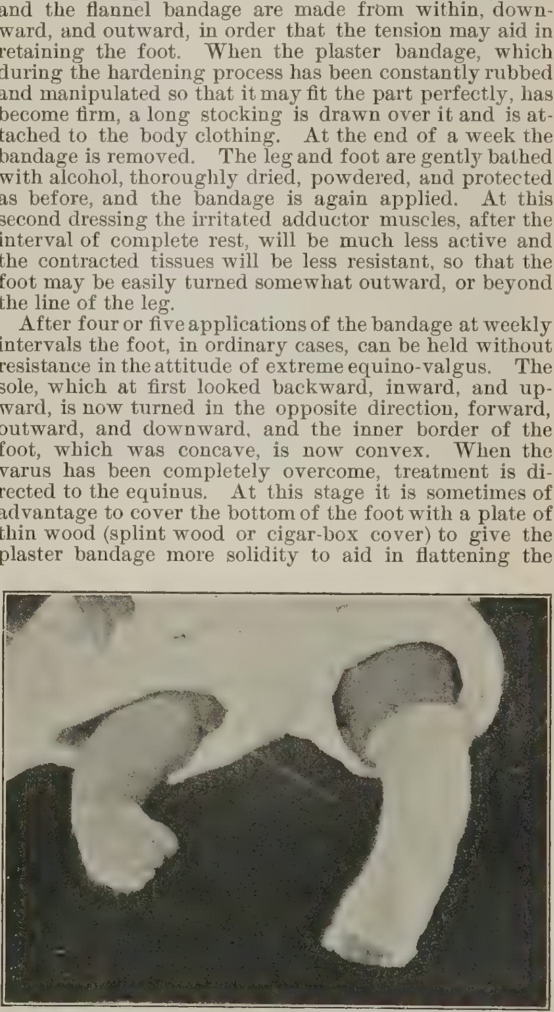

FIG. 2150.—The First Application of the Plaster Bandage, Showing the Improved Position.

force is required, sufficient to cause some discomfort during the application of the plaster, but not sufficient to cause suffering afterward. The force is applied by means of the sole plate to the entire foot so that the posterior extremity of the os calcis may be drawn downward by actual lengthening of the tendo Achillis, and not, as is often the case, by an over-correction of the forefoot, while the heel remains in its original position of plantar flexion. By the proper application of force the equinus is gradually overcome; the sharp indentation or fold at the insertion of the tendo Achillis is lessened, and the heel becomes more prominent.

The reduction of the equinus may be somewhat more difficult than that of the varus, but it should be entirely corrected in three or four months from the time of beginning the treatment.

As has been stated, correction of the deformity implies over correction; and it is well when this has been attained to hold the foot for several weeks, by means of the plaster bandage, in an attitude of extreme pronation and dorsal flexion (calcaneo-valgus) in order to impress, as it were, the new position upon its structure.

This concludes the first stage of the treatment, the simple rectification of deformity.

Correction by the plaster bandage has the great advantage of placing the treatment entirely under the command of the surgeon. When properly applied, the support fits perfectly and holds the foot in the desired attitude without undue pressure.

The disadvantages of the treatment are almost entirely due to its improper application. For instance, the bandage may be too heavy, or the padding may be so thick that it does not retain its position. Excoriations are usually due to carelessness in the application of the bandage or they result from a failure to remove it in proper season. The fear of compression, of atrophy of muscles, of stunting the growth of the limb, is groundless. At the end of the retention treatment the corrected foot is, as a rule, larger than one that has remained untreated. The stunted foot is the result of non-treatment, or of ineffective treatment by braces or otherwise; not of the enforced rest necessitated by the methodical reduction of deformity.

It may be noted in this connection that the normal infant moves the foot in various directions in a more or less regular alternation of postures, while in club foot motion is in one direction only, that toward which the foot is turned. The muscles on the back and inner side of the leg, which are alone active, become relatively irritable and hypertrophied as compared with those on the front and outer side that are disused. Thus, muscular activity of the deformed foot is in reality harmful, because it increases deformity and still further disturbs the muscular balance. For this reason the temporary restraint of motion, necessary during the rectification of the deformity, may be considered rather of advantage than otherwise. When movement is again allowed and encouraged, it must be in the directions opposed to the attitudes of deformity, with the aim of so strengthening the weakened group of muscles at the expense of the stronger, that the balance of muscular power may be re-established.

Correction of deformity may be accomplished by holding the foot in an improved position by strips of adhesive plaster, or by the elastic traction of rubber bands attached to the leg and foot. As compared with the ease, rapidity, and certainty of correction by the plaster bandage, such methods are uncertain and ineffective and they will not therefore be described in detail.

The Rectification of Deformity by Splints and Braces: Of mechanical supports there are many varieties. Complicated appliances should be avoided because they are unnecessary, and because they serve to distract attention from the prime object of treatment, the rapid and systematic correction of deformity.

Of the simpler braces, that used by Judson of New York is one of the best and will serve as a type to illustrate this form of treatment. The method of application may be described in Judson's own words:

"The apparatus which I have conveniently used to effect this reduction before the child learns to stand is a simple retentive brace which acts as a lever making pressure on the outer side of the foot and ankle, at *A*, in Figs. 2151 to 2153, inclusive, and counter-pressure at two points, one on the inner side of the leg, at *B*, and the other at the inner border of the foot, at *C*. It is advisable to keep in mind that this simple instrument is a lever, because, if we know that we are using a lever with its three well-defined points of pressure, we can make the apparatus more efficient than if we view it, in a more general way, as an apparatus for giving a better shape to the foot.

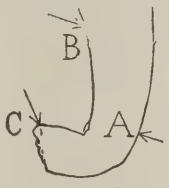

FIG. 2151.

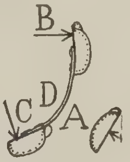

FIG. 2152.

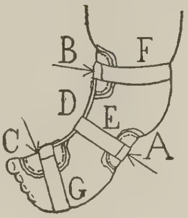

FIG. 2153.

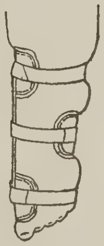

FIG. 2154.

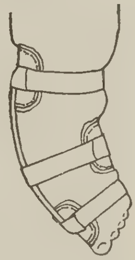

FIG. 2155.

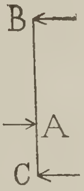

FIG. 2156.

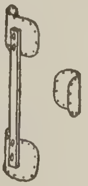

FIG. 2157.

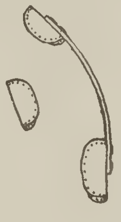

FIG. 2158.

"I use a little brace made of sheet brass, doing the work with a few simple tools. An advantage of doing the work one's self is that there is no room for doubt as to where the blame lies if the apparatus does not work well. Two curved discs, *B* and *C*, Figs. 2152 and 2153, are riveted to a shank, *D*, and thus is formed that part of the brace which applies the two points of counter-pressure, while, on the other hand, the point of pressure is brought into action by a third disc, or shield, *A*, which is drawn tightly against the outer side of the foot and ankle, and held in place by a strip of adhesive plaster *E*, which includes the limb and the piece which connects the two discs, *B* and *C*. The discs are lined with two or three thicknesses of blanket, easily renewed, when necessary, with a needle and thread. These braces are so cheap and easily knocked together that it is nothing to apply new and larger ones, using heavier material for the shank as the child grows. In general, three sizes will be enough, the shanks being 12 gauge, ⅜ in. wide; 14 gauge, ½ in. wide; and 16 gauge, ⅝ in. wide. The discs are conveniently made from 22 gauge, 1¼ in. wide. The rivets are copper belt-rivets, No. 13. A lip turned on the edge of the discs, with the flat pliers, gives stiffness to the thin brass, and protects the skin from the rough edge. If more easily obtained, tin discs, light bars of iron or steel, and ordinary iron rivets, would doubtless answer. (See Figs. 2152, 2157, and 2158.)

"The brace is applied with three strips of adhesive plaster. The upper and lower pieces, *F* and *G*, Fig. 2153, are simply to keep the apparatus in place, which they do effectively if ordinary gum plaster is used, while, by drawing the middle strip, *E*, tightly over the shield, and straightening the brace from time to time, the deformity is gradually and gently reduced. At each re-application the brace is made a little straighter than the foot at that stage. This may readily be done by the hands, and then the adhesive strip is to be tightened over the shield till the shape of the foot agrees with that of the brace. After a few days, the brace is to be made still straighter and again re-applied, and made tight till another point of improvement is gained. The brace is applied very crooked at the beginning of treatment, as in Figs. 2152 and 2153, and is straightened from time to time, and a longer brace applied as the deformity is reduced and the patient grows. It should be removed every week, or two weeks, and an interval of a few days allowed for freedom from the brace, when the mother is advised to manipulate the foot constantly, using as much force as she will in the direction of symmetry. Manipulating the foot during these intervals is of great importance, as cases have occurred in which varus and equinus have been entirely overcome by the mother's hand alone.

"By this simple and prosy treatment, carried out systematically and without haste, or violence, or pain, the foot, unless it is a frightful exception, may with certainty be changed from varus to valgus. At the same time the tendo Achillis is lengthened till the position of the foot is near the normal, or at right angles with the leg, as the result of manipulation and giving the brace from time to time a partly antero-posterior action. Figs. 2152 and 2153 show approximately the shape of the brace at the beginning of treatment, Fig. 2154 when the varus is reduced, and Fig. 2155 when valgus has taken the place of varus. The foot, in this latter stage, may not hold itself valgus, when left to itself, but with almost no force and with one finger it may be pushed into valgus."

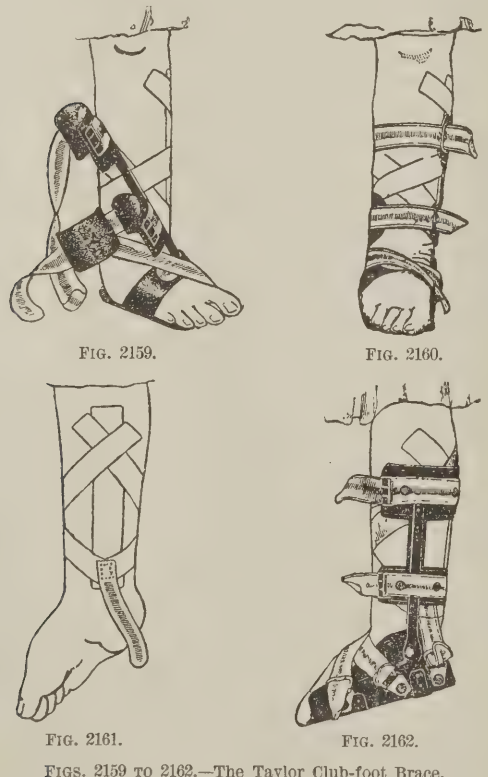
FIG. 2159. FIG. 2160.

FIG. 2161. FIG. 2162.

FIGS. 2159 TO 2162.—The Taylor Club-foot Brace.

When the varus deformity is reduced, the equinus is gradually corrected by carrying the splint behind the internal malleolus, and finally, if necessary, direct upward pressure may be obtained by lengthening the brace and applying it to the posterior aspect of the foot and leg.

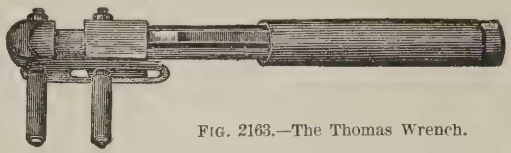
FIG. 2163.—The Thomas Wrench.

It may be noted that manipulation and stretching of the contracted parts when the brace is removed, is of much importance in the correction of deformity by this or other means. Splints of wood, tin, felt, and the like may be employed, but they present no particular advantage over that which has been described.

Tenotomy: The equinus has been spoken of as the secondary deformity, but its complete correction is sometimes more difficult than that of varus. The mechanical stretching of the contracted parts by means of the plaster-of-Paris bandage, or the brace, is often accomplished with ease, but in more resistant cases time will be gained after the foot has been forced into the position of equino-valgus, by the division of the tendo Achillis, which is the most resistant of the shortened tissues. After division of the tendon it may be necessary to use considerable force to stretch the other contracted parts, and to force the foot up to the limit of normal dorsal flexion, which is the object of the operation. Occasionally the obstacle seems to be in the posterior ligament of the ankle, and it is sometimes of service to re-insert the knife and to divide this structure, in part at least, so that it will give way under manipulation. When the foot has been forced into the position of over-correction, it is fixed in a plaster bandage which is allowed to remain for several weeks, until the interval between the separated ends of the tendon is filled in with the new tissue.

In many instances the leg is rotated inward upon the thigh, an attitude that is accompanied by accommodative changes in the ligaments of the knee joint. During the rectification of the club foot, this secondary distortion may be corrected, in part at least, by forcible manual rotation of the leg outward on the thigh, several times daily.

The management of the first stage of the treatment of infantile club foot is then—manipulation by the nurse or parents from birth until systematic rectification can be begun,—mechanical correction, first of the varus and then of the equinus deformity, terminating with a period of retention in the over-corrected position (calcaneo-valgus). Division of tendons, other than the tendo Achillis, is not often necessary. The time required for the first stage of treatment, or over-correction of deformity, should not under favorable conditions exceed three months.

The rapid and complete correction of deformity in the manner described, begun as early as possible and accomplished as quickly as possible, cannot be too strongly urged. In the first months of life the tissues are not resistant, the bones are in large part cartilaginous, and when the foot in its external appearance is rectified, the rapid growth in the first months of life will change the internal structure to conform to the normal conditions. The fear of atrophy, compression, or other harm from the temporary fixation necessary during rectification is groundless, and in fact exercise, so-called, except in the direction opposed to deformity is harmful rather than beneficial.

The Second Stage of Treatment: Support and Restoration of Function.—When the deformed foot has been corrected, in the sense that all normal motions are unhampered, the first and most difficult part of the treatment will have been completed, and in some instances a practical cure is assured. Such a result is unusual, however, for although the foot may be normal in appearance, its muscular balance has not been restored. This is shown by the fact that there is little power in the dorsal flexors and abductors to draw the foot upward and outward. For this reason, the foot must be supported in proper position until the slack of the lengthened tissues has been taken up by development in the normal attitude, otherwise the deformity must recur. Practically, support is always necessary until the child has begun to walk.

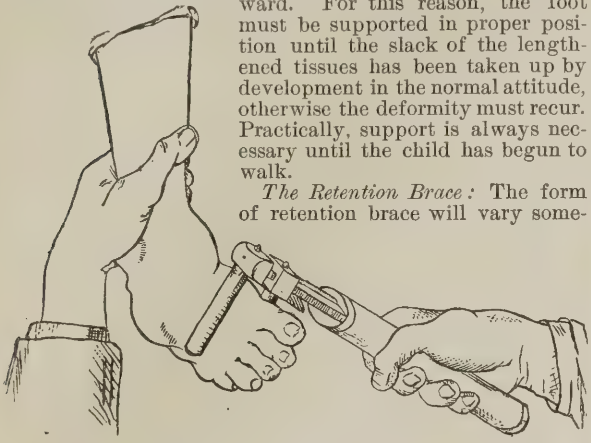

FIG. 2164.—The Thomas Wrench Applied to a Case of Talipes Equinovarus.

The Retention Brace: The form of retention brace will vary somewhat according to the indications of the individual case, the one essential being that the foot shall be supported in normal position, or better, in an attitude of slight dorsal flexion and abduction. One of the best supports is the Taylor brace, the invention of Dr. C. F. Taylor of New York. This consists essentially of a light upright that extends along the inner side of the leg to the knee, and a thin steel foot plate of the exact size of the sole, with an upright flange on the inner side rising to a point just above the dorsal surface of the foot, against which the foot is closely pressed so that recurrence of the varus deformity is prevented. The joint at the ankle is provided with a catch that prevents plantar flexion, but allows dorsal flexion (Figs. 2159, 2160, 2161, and 2162). By bending the upright and the sole plate the foot may be held in slight abduction. The apparatus is applied with straps as illustrated, and if necessary its position is further fixed by a band of adhesive plaster applied on the inner side of the leg to hold the heel firmly against the foot plate. The foot is thus held constantly at a right angle to the leg, or better, in the early stage of treatment, in an attitude of dorsal flexion and valgus. Occasionally, after complete rectification of the deformity, the foot still turns in. In most instances this is due to an inward rotation of the tibia on the femur at the knee joint, but in some cases it is caused by a spiral twist of the tibia itself. In order to correct this secondary deformity the upright of the brace is carried beneath the leg, provided with a joint at the knee, and is extended up the outer side of the thigh. At the hip it is attached by a free joint to a padded pelvic band of light steel. The band holds the upright in the proper relation to the thigh; thus, by twisting the part below the knee the foot can be rotated outward to the desired degree. In less marked cases, the retention bands used for pigeon toe may be employed. (See Pigeon Toe.)

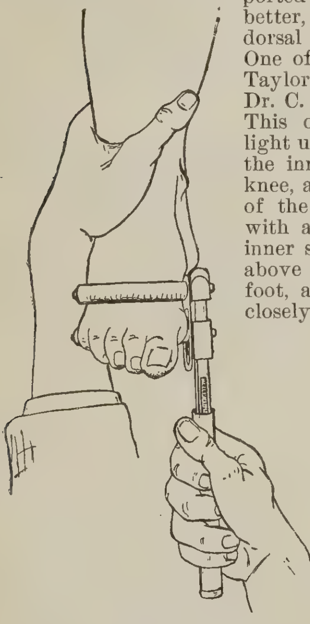

FIG. 2165.—The Deformity Partially Corrected by the Wrench.

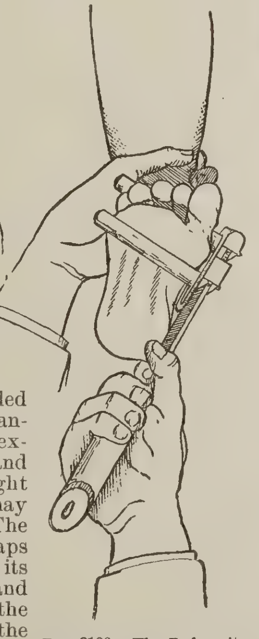

FIG. 2166.—The Deformity Fully Corrected by the Wrench.

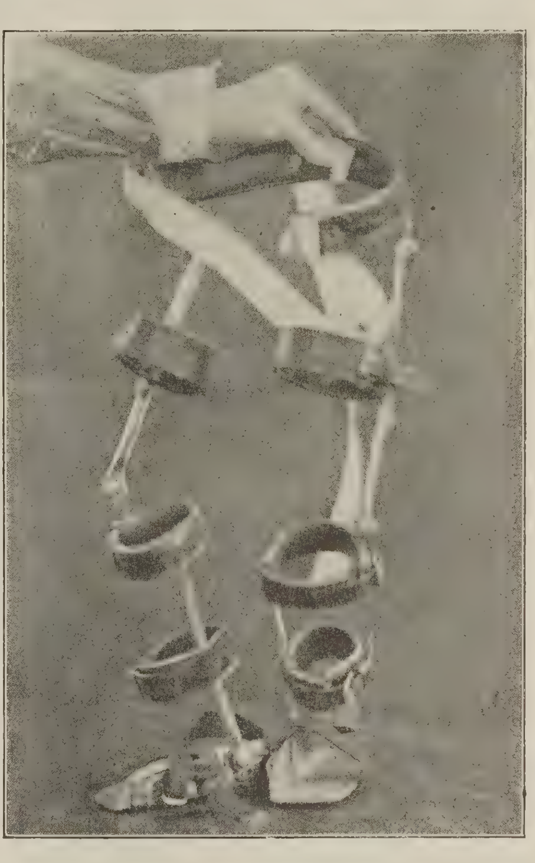

FIG. 2167.—Club-Foot Braces, to Correct Inward Rotation.

Methodical Manual Correction: Several times during the day the brace should be removed in order that the foot may be thoroughly massaged and forcibly abducted, that is, twisted outward at the medio-tarsal joint so that the inner border is made convex, and then to the extreme limit of dorsal flexion and abduction. If the leg is rotated inward, it is forcibly turned outward on the femur. Even if the tibia is actually twisted on its long axis, the influence of the brace and forcible manipulation will usually correct the deformity. If not, an osteotomy of the tibia may be required at a later period; this, however, is not often necessary. Active contraction of the weak muscles may be induced by tickling the sole of the foot or by the use of electricity; and finally, the entire limb should be thoroughly massaged before the brace is re-applied.

When the ability to dorsiflex and abduct the foot has been regained, the brace may be removed for a part of the day; later it is used only at night, and finally it may be discarded if the child walks normally. But it is best to continue the daily manipulation, more particularly the systematic stretching or over-correction of the foot, for a long time. Thus one may check the tendency toward deformity of which the first sign is always a slight limitation of the range of dorsal flexion and abduction.

In many instances the deformity may have been so thoroughly over-corrected by the plaster-of-Paris bandage or by the brace, and the after-treatment of massage and stretching may have been so efficiently applied by the nurse or parent that no support is required after the child begins to walk. On the other hand, the inclination toward deformity may be so marked that it may be necessary to hold the foot in slight abduction and valgus for a year or longer.

In other cases, the use of a light brace to hold the foot in the over-corrected position during the night is alone required. These are points to be decided by the circumstances of each case. The period of observation and supervision is included in the final stage of the treatment.

Third Stage of Treatment: Supervision.—During this period the attitudes of the limb and foot of the child in walking must be carefully watched and one should observe the signs of wear on the sole of the shoe. If it shows greater wear on the outer side than is usual, it is an indication that the weight does not fall on the centre of the foot and that there is therefore a tendency toward deformity. This must be counteracted by making the sole thicker on the outer border, or somewhat wedge-shaped, so that the weight may be deflected toward the inner side.

This third period of treatment, or rather of oversight of the functional use of the foot, must be continued indefinitely. In fact, it is the quality of this final supervision that decides in most instances whether the ultimate outcome is to be what is called a satisfactory result, or a perfect cure.

The Treatment of Neglected Club Foot.—The treatment of club foot, under what may be called the proper conditions, as outlined in the preceding pages, applies practically to all cases before the completion of the first year of life, and mechanical rectification may be successfully employed in cases far beyond this limit of age. As a rule, however, when the patient has walked for any length of time, the resistance of the tissues has increased to such an extent that more rapid and effective treatment is indicated. The investigations of Wolff have shown that the internal structure of the bones corresponds to their external contour, and that the structure and contour are adaptations to functional use. This internal structure is not, however, permanent, but is readily transformed to conform to changes in form or function. If then the external contour of the club foot were suddenly reversed, and if use of the foot were permitted in this new attitude, a transformation of the internal structure of the bones and at the same time of their shape would begin at once. This would continue until both structure and shape had become adapted to habitual function. It is upon this natural power of transformation that one depends for the final and complete change of the distorted bones to the normal; and what is true of a resistant structure like bone is equally true of the other constituents of the deformed foot.

Age as Influencing Treatment.—There is then this very essential difference between the indications for treatment in infancy and in childhood. In the first instance the foot has no essential function. In the walking child, however, the weight of the body and habitual use tend to confirm and to increase the deformity. As a general principle of treatment, therefore, walking should not be permitted until the weight of the body may aid rather than retard the correction of deformity. This is another point in favor of rapid, as opposed to gradual, correction of deformity.

The Rapid Correction of Deformity.—The principles on which operative treatment is conducted are the same as those which govern mechanical treatment. Thus the deformed foot must be over-corrected, and it must be held in the over-corrected position, until the immediate tendency toward deformity has been overcome. It must then be supported until the foot has become adapted to its new position and until the balance of muscular power has been regained. No surgical operation, however radical, can be, in childhood at least, curative by itself alone. Operative procedures are undertaken simply for the purpose of making the primary over-correction possible, and that operation by which this object can be accomplished, with the least interference with the structure of the foot, should be selected. Such an operation is what may be called forcible manual correction.

*Forcible Manual Correction.**—The patient having been anæsthetized, one first attempts to correct the sharp inward twist at the medio-tarsal joint. Supposing the right foot to be deformed, one grasps the heel with the right hand, in such a manner that the projection or muscular part of the palm lies on the outer aspect of the foot, against the most prominent part of its outer border, which is at the junction of the os calcis and cuboid bones. This hand serves as a fulcrum, over which the inverted foot may be bent. The forefoot is then grasped firmly by the left hand and one begins a series of outward twists over the fulcrum of the opposing palm, gently at first with alternate relaxation of pressure, but with gradually increasing force as the resistant tissues stretch under the tension.

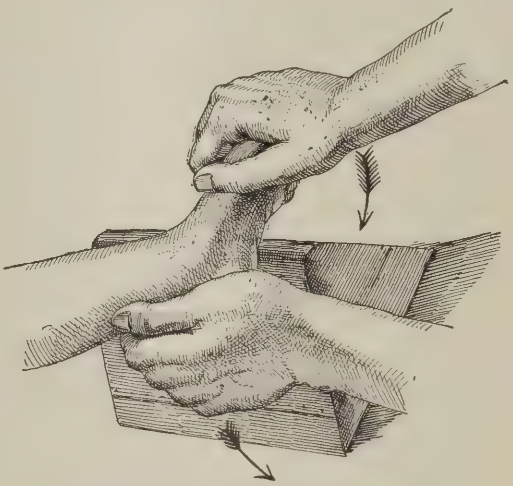

FIG. 2168.—Reduction of Varus. (After Lorenz.)

If greater force is required, a triangular block of wood, well padded, may be used as the fulcrum (Fig. 2168), one hand pressing on the heel and the other on the forefoot; but there is a great advantage in using nothing but the hands, because one feels sure that no injurious force is likely to be exerted. Under this steady manipulation, the foot soon loses its rigidity and its elastic recoil toward deformity; it becomes so limp that with two fingers one can not only hold the sole straight, but can push it or bend it outward. Thus the first stage of the methodical correction has been accomplished.

One then turns his attention to the supination which makes the outer border of the foot lower than the inner border. The leg is grasped firmly near the ankle with the left hand, and with the right the foot is forcibly twisted in a direction downward, outward, and upward, over and over again, with steadily increasing force as the tissues slowly yield, until it may be forced into a position of extreme abduction, so that the sole may be made to look outward and downward—the reverse of the former attitude.

One next stretches the contracted plantar fascia and reduces the cavus, which is usually present, by forcing the forefoot toward dorsiflexion, against the resistance of the contracted tendo Achillis, until the sole is made perfectly flat (Fig. 2169). Finally, the fourth, and often the most difficult part of the rectification, that of forcing the displaced astragalus into its proper position between the malleoli, is attempted. To accomplish this, the tendo Achillis is first divided subcutaneously, and if necessary the posterior ligament of the ankle is also divided at the same time. The patient is then turned upon his face so that with the knee resting on the table the leg is held upright. This allows one to hook the fingers about the extremity of the os calcis while the hand and arm, lying along the sole of the foot, may be used as a lever to force it toward dorsal flexion as the os calcis is drawn downward. In this manner forcible stretching is continued until the dorsum of the foot can be brought almost into apposition with the crest of the tibia. When the operation has been completed, the foot should be perfectly limp. It is usually somewhat congested from the pressure of the fingers, but it is warm and the circulation is unimpaired.

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* First described by Delore, of Lyons.

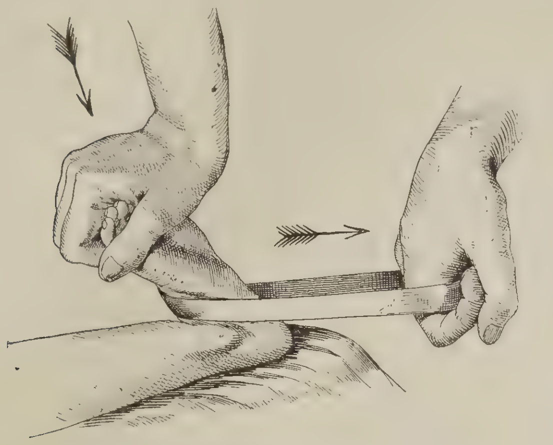
FIG. 2169.—Reduction of Cavus. (After Lorenz.)

One may assume that in the change that has taken place from rigid deformity to a limp foot that can be moulded into any position, the component parts of the deformed foot must have been subjected to considerable violence; that ligaments and muscles must have been stretched and, it may be, ruptured; that new surfaces are now opposed to one another in the articulations, and that the bones have been forced into approximately normal position. This method of treatment has a great advantage over the ordinary operative treatment, in that the entire foot has participated in the correction, instead of a limited portion, as when, for example, bone is removed by cuneiform osteotomy; and it has a second and almost equally important advantage, in that the immediate use of the corrected and yielding foot is possible in the place of the necessary rest that must follow cutting operations. For these reasons forcible massage should be the operation of choice, and preliminary, at least, to more severe procedures in the treatment of resistant club foot in childhood. The only disadvantage of the operation is the actual labor which it necessitates on the part of the surgeon, usually twenty minutes or more of rather exhausting work.

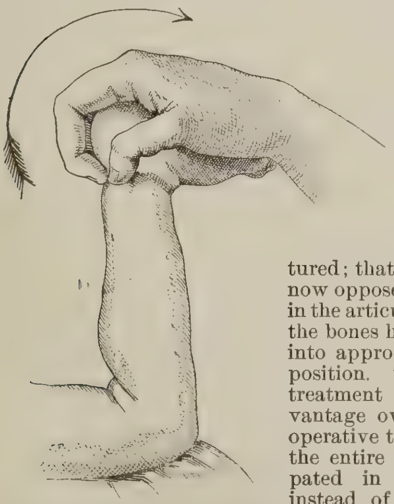
FIG. 2170.—Reduction of Equinus. (After Lorenz.)

The foot must now be fixed by a plaster bandage in an over-corrected position. It is first evenly covered with a layer of cotton and a bandage of canton flannel, and while it is held by the assistant, the plaster bandages are applied from the tips of the toes to the upper part of the thigh. It is important that the toes should not project beyond the bandage, because of the swelling that sometimes follows. It is important, also, that the foot should be held in the proper position while the bandage is hardening, and that it should not be manipulated to any extent after the bandage is applied, in order that no rigid wrinkle may press against the skin. The bandage is applied to the thigh in most instances in order that the tibia may be rotated outward to its normal position and held there, and because more effective fixation may be assured and greater pressure exerted on the foot in walking. To utilize this pressure to better advantage the bandage is made very thick beneath the sole, and a thin foot plate of wood should be incorporated in the plaster. When the bandage is applied the position of the foot should be that of over-correction of deformity, flexed beyond the right angle, twisted far outward, and the outer border should be elevated considerably beyond the level of the inner border (Fig. 2171).

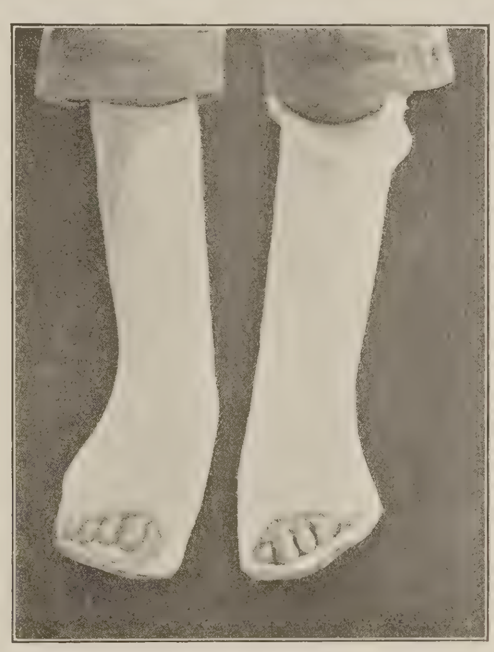
FIG. 2171.—The Feet Fixed in an Attitude of Over-Correction.

One would suppose, after using the force that has been necessarily applied, that much pain and swelling would follow. This is, however, not the case. Often, on the following day, the patients are able to stand upon the foot, and always within the first week if the bandage has been properly applied. The pain following this operation is far more often caused by pressure of an ill-fitting bandage than by the violence that has been used. Thus one should be careful to remove sections of the bandage if it appears to cause undue discomfort. These points are usually the front of the ankle, the back of the heel, and the inner border of the great toe.

The immediate use of the foot is encouraged, and although only the heel and inner border bear weight directly, yet the pressure of the foot plate on the parts that do not come in contact with the floor is usually sufficient to mould the foot into its proper shape. If greater pressure is thought necessary, wedges of wood or cork may be attached to the sole of the plaster bandage so that all parts may bear weight equally. The bandage is covered by a stocking, a slipper may be worn indoors, and an ordinary overshoe for street wear.

The first bandage should be removed at the end of about three weeks, as by that time it will have become loose. The foot will then be found to be extremely flexible, and by an enthusiast it might be considered cured. But knowledge of its previous condition should make it evident that a much longer time is necessary to allow for its consolidation in the new position. At this time almost no evidence of the operation remains, except, it may be, slight discoloration of the skin. The foot is again held as far as possible in the over-corrected position and another plaster bandage is applied, usually as far as the knee only. This should remain for eight weeks, or longer if it is still unbroken. The patient uses the foot constantly, and is drilled in the proper method of walking, so that the muscles of the leg may become accustomed to the new and normal attitudes.

At the end of another month or more, the plaster is replaced by a brace to be worn inside the shoe, usually of the simplest description, consisting of an upright bar with a calf-band, attached to a steel sole plate by a joint that will allow dorsal flexion but checks extension at a right angle. This is applied because the dorsal flexors, after years of disuse, only slowly recover sufficient power to resist the action of the opposing group and the force of gravity.

The second stage of the treatment is now begun. This may be divided into a period of active treatment and one of supervision. The first, or treatment stage, consists in massage of the entire leg and of the foot to stimulate the growth of the atrophied muscles, and methodical manipulation of the foot several times a day by pushing it with the hand to the extreme of the range of motions possible immediately after the operation, viz., eversion, abduction, and dorsal flexion, in the same order as at the time of operation. At the same time the patient attempts voluntarily to carry out these motions by his own muscles, the power being supplied by the hand of the masseur. Slowly the muscles gain in strength and ability and when normal muscular power and balance have been regained the patient is practically cured; but for long afterward supervision is kept up of the patient's attitude, of the manner of using the foot, of the wear of the sole of the shoe, and the like, and by constant drilling and stimulation the attempt is made to restore the normal appearance and function.

One cannot exaggerate the importance of this after-treatment, and of supervision at least on the part of the surgeon. The active treatment may often be left to the parents. But constant supervision is necessary to keep this after-treatment, which seems so commonplace and simple, up to the proper pitch; and to assure one's self that the range of motion regained by the operation does not gradually become more and more restricted, even though the contour of the foot appears to be normal.

Forcible manual correction may be employed with advantage from the second to the tenth year, although the limits may be extended in either direction in special cases. In this operation, as described, the tendo Achillis is the only structure divided. There is no particular objection to subcutaneous division of other tendons or ligaments in connection with forcible manual correction; but in such prolonged manipulation it is much better if the skin, which itself must be stretched, is unbroken and dry, rather than moist from the bleeding from punctured wounds. For this reason it is well to correct the deformity without extensive tenotomy if possible.

Treatment of Secondary Deformities.—In cases such as have been described a certain amount of secondary deformity of the leg is often present. Knock-knee rarely requires other treatment than daily manual correction in connection with the massage of the foot and leg.

Hyperextension at the knee will correct itself during the treatment of the foot, which, being fixed in an attitude of dorsal flexion, obliges the patient to walk with the knees slightly flexed. Inward rotation of the leg upon the thigh may be sufficient to require a brace, but, as a rule in childhood and adolescence, the patient has so long walked with exaggerated outward rotation of the femur that after correction of the deformity no inward rotation of the foot appears, even though inward rotation of the tibia be present. Osteotomy of the tibia, to correct the inward twist, is rarely necessary.

Malleotomy.—In confirmed club foot of the type under consideration, the chief obstacle to perfect correction may be the astragalus. This is often displaced forward, downward, and inward, so that only the posterior portion of its articulating surface is contained within the malleoli. In the cases of long standing the spaces between the bones may have become insufficient for the anterior and wider part of the body of the astragalus. In such instances, even after division of the tendo Achillis and the posterior ligament of the ankle, dorsal flexion still remains restricted, and examination shows that the astragalus still projects as before, although the foot has been forced into a position of apparent dorsiflexion and abduction. This apparent correction is the result of over-correction at the medio-tarsal joint, of outward rotation of the tibia upon the femur, and of backward displacement of the fibula. In such cases the malleoli may be separated from one another by dividing the ligaments that hold them in apposition.

A straight incision, about two inches long, is made on the outer side of the ankle directly over the anterior aspect of the articulation, the ligaments are divided and by inserting a thin chisel the bones are pried apart, and the astragalus is replaced in the proper position. This is usually easy if the restraining tissues on the posterior part of the ankle have been divided. The wound is then closed and the foot held in the over-corrected position by a plaster bandage. Complete correction of the varus deformity should, of course, precede this operation.

It would seem on first consideration that if immediate correction of deformity could be so easily accomplished in the confirmed case, it should be employed even in infancy. There are, however, practical reasons against it; first, because the foot is so small that it cannot be easily manipulated; second, because even after it is corrected it must be supported until the child begins to walk; and third, because the foot can be so easily straightened without an operation, which, even of so slight a character, is sometimes cause of much anxiety to the parents. For these reasons, although immediate reduction of deformity is a thoroughly practical and safe operation, it is rarely advised until a later time.

Subcutaneous Tenotomy.—The division of tendons and other tissues by the subcutaneous method has been mentioned incidentally, but as it has so long occupied an important, and even at one time the most important, place in the treatment of club foot, the operation and its effects may be described somewhat in detail.

Tenotomy, as has been stated, is performed for the purpose of removing an obstacle to the correction and over-correction of deformity. In the acquired or paralytic form of club foot, one or more shortened tendons may be the chief obstacles to reposition, but in the congenital form, in which all the tissues have grown into deformity, the shortened tendons are by no means the only resistant parts, and tenotomy should be considered, therefore, merely as an incident in correction. In the ordinary treatment of infantile club foot, tenotomy may often be dispensed with, and in the great majority of cases division of the tendo Achillis is alone required.

When the tendon has been divided, the deformity is immediately over-corrected; thus the two extremities are separated to the extent necessary to allow the improved position. At the end of three weeks or more, when the first dressing is removed, the space will be filled with new material, and in another month the splice, which will be somewhat larger and thicker than the normal, should be strong enough for use. The slight thickening at the site of the operation may be felt for a year or more, but for all intents and purposes the new and lengthened tendon is perfectly normal, as is the function of the muscle of which it is a part.

The process of repair is somewhat as follows: Immediately after the operation the space between the divided ends of the tendon is filled or partially filled with blood; then leucocytes appear, which with those in the blood clot serve as pabulum for the plasma cells which migrate from between the fasciculi of the tendon and from the tendon sheath. The fibrin and red corpuscles of the clot are absorbed, the extremities of the divided tendon soften and become fused with the new material, which begins to take on the form and consistence of true tendon, and to separate itself from the adherent sheath. This new tendon, according to Tubby, differs from the normal structure in that the fibrous fasciculi are more irregular and its substance is more like scar tissue, but practically it is perfectly normal in its appearance and function.

Since the tendon sheath serves an important purpose in repair, it should be disturbed as little as possible, and for this as well as for other obvious reasons, subcutaneous tenotomy of the tendo Achillis, which is so prominent and so distinct from other important parts, is to be preferred; but if more extensive division of other tendons is required, the open operation is often indicated.

Division of the Tendo Achillis: For this operation anæsthesia is usually required, preferably by means of nitrous oxide gas, and it is hardly necessary to state that surgical cleanliness, even in so slight a procedure, is essential.

The instrument should be small and very sharp so that no force is required in the operation; the blade should be as long as the tendon is wide. The patient is turned upon the side or to the prone position, so that the foot may be held with the heel upward by the left hand. The position and size of the tendon are ascertained by careful palpation, and the knife is then inserted to its inner side, at about the level of the extremity of the internal malleolus. The flat surface of the blade is held parallel to the tendon, and it is passed beneath it until its point can be felt beneath the skin on the opposite side. The edge is then turned upward, and the tendon, being made tense, is divided by a sawing motion of the knife. When the division is complete, as indicated by the separation of the divided ends, the knife is withdrawn, and the minute opening in the skin, from which there is usually slight bleeding, is covered with a pledget of aseptic cotton. The foot is forced into dorsal flexion and is securely fixed by a plaster bandage. In applying the dressing one should take care that no pressure is brought upon the seat of operation, as this might interfere with the effusion of plastic material. As soon as the discomfort attending the operation has subsided the patient is encouraged to stand and to walk. Functional use, far from retarding repair, is, by stimulating the circulation, an important agent in assuring firm and rapid union.

Division of the *plantar fascia* is not infrequently necessary and should be performed subcutaneously. The tenotome is inserted beneath the skin at about the centre of the concavity to one or the other side of the central band of the fascia, which is divided by a sawing motion of the knife. The part is put upon the stretch, and other resisting bands to the outer and inner side are divided in the same manner; the cavus is then corrected by manual or instrumental force. The operation, like that upon the tendo Achillis, is practically free from danger.

Division of the *tibialis anticus* is not often necessary, as this tendon offers little resistance to the rectification of deformity.

The tendon of the *tibialis posticus* may be divided together with that of the tibialis anticus near the points of attachment. If the operation is required, it may be combined with simultaneous section of the *calcaneo-scaphoid ligament,* with which are blended the anterior part of the deltoid and fibres of the anterior ligament of the ankle.* According to Parker's directions, the foot should be strongly abducted to make the parts tense. The tenotome is entered directly in front of the anterior border of the internal malleolus, its cutting edge being turned forward between the skin and the ligament. It is then turned toward the ligament, and the tissues are divided to the bone. The blade is then made to enter the interval between the astragalus and the scaphoid, and is carried downward and forward to divide the inferior part of the ligament and at the same time the tendons of tibialis anticus and posticus.

The posterior ligament of the ankle joint may be divided or sufficiently weakened, so that it may be ruptured after section of the tendo Achillis by passing the knife directly downward in the middle line upon the upper border of the astragalus.

FIG. 2172.—Resistant Club-Foot in Adolescence.

Forcible Correction of Deformity by Means of Osteoclasts and Wrenches.—In place of manual correction of deformity greater force may be employed by means of osteoclasts or wrenches. There is this important difference between the two procedures: force may be applied by the hands for as long a time as is necessary with but little danger of injury, while force applied by a machine must be momentary because of the pressure and strain on the parts where the leverage is exerted. Manual force, continuously applied, may be supposed to stretch the resistant parts, and although much less power is exerted it is often more effective than the sudden and momentary force of the wrench or osteoclast.

Correction by means of the Thomas wrench is one of the simplest and most efficient of these procedures. The wrenching may or may not be preceded by tenotomy, a point to be decided by the resistance of the parts. As a rule division of the tendo Achillis is alone necessary. The instrument is a simple heavy monkey wrench, of which the jaws have been replaced by two strong pins slightly bulbous at the ends to keep the covers of rubber tubing from slipping off (Figs. 2163–2166).

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* Parker: "The Astragalo-Scaphoid Capsule."

The wrench is applied to the inner side of the foot and screwed down, so that it may "bite" and hold its place firmly, for if it slips it is likely to abrade or tear the skin; then with considerable force the foot is twisted outward and upward. The "keynote" of the operation is so to wrench the foot that it loses its elasticity, and shows no tendency to recoil toward deformity. The foot is then placed in the best possible position and retained there by the Thomas foot splint or by a plaster bandage. In certain instances one may complete the rectification at one operation, but this is not usually attempted, the procedure being repeated at intervals of a few days until the deformity has been over-corrected. In very resistant cases eight or ten applications of force may be necessary. When the deformity has been rectified, the foot is held in the over-corrected position for several weeks by the splint or plaster bandage.

As a walking appliance, a simple upright of iron with a calf band is applied to the inner side of the leg from a point just below the knee to the heel of the shoe, into which it is inserted, as is the Thomas knock-knee brace. By bending the upright the foot may be kept in slight valgus, and this position is still further assured by making the outer side of the sole of the shoe thicker than the inner, so that the weight falls upon the inner border of the foot.

In many instances the walking brace may be dispensed with in the after-treatment, but a light brace is usually worn to hold the foot in the corrected position during the night, until the power of the abductors and dorsal flexors has been regained. Massage and manipulation are used in the after-treatment in the manner already described.

Properly applied the treatment is satisfactory and free from danger. Sloughing of the tissues caused by the pressure of the instrument or by the plaster bandages has been reported, but such accidents have not occurred in the extensive practice of Thomas and Jones.

Correction by Means of the Osteoclast.—The late Mr. Grattan, of Cork, used the osteoclast that goes by his name to crush and to over-correct resistant club foot. The operation may include, besides the correction of deformity of the foot itself, fracture of the leg above the malleolus to turn the foot toward valgus, and a second fracture half-way up the limb, to overcome the twist of the tibia.

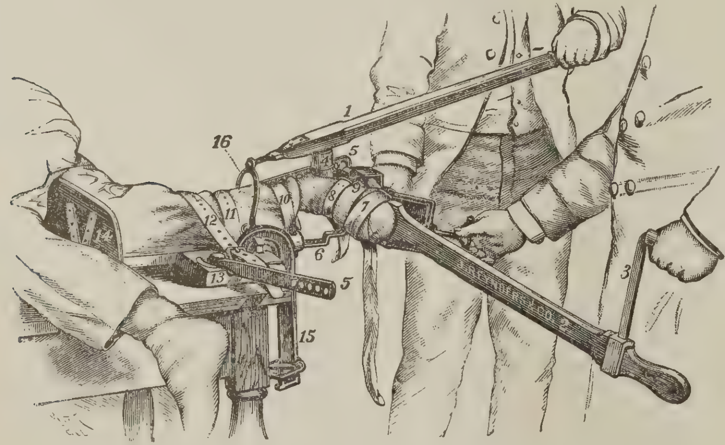

FIG. 2173.—Phelps' Machine in Use for the Correction of Club Foot in the Adult.

Other appliances constructed on somewhat similar principles may be employed. Of these the Lorenz osteoclast and the Bradford lever apparatus are the most effective.

The Open Incision Combined with Forcible Rectification of Deformity—Phelps' Operation.—When extensive division of soft parts is indicated, as in resistant cases, the open incision is to be preferred because of the opportunity thus offered for the recognition and for intelligent selection of structures that require division in the final correction of the deformity.

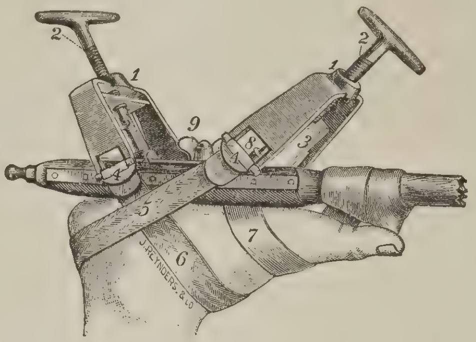

FIG. 2174.—Phelps' Machine Adjusted to the Foot.

Phelps' operation is in all essential respects simply the division of the contracted parts through an incision on the inner border of the foot, combined with the manual or instrumental force sufficient to over-correct the deformity. It is the most conservative of the more radical procedures, and by it even the most severe type of deformity in the adult can be corrected; that is to say, the deformity may be overcome and a serviceable foot may be assured to the patient. Perfect functional cure is not possible when deformity has become habitual after many years of neglect.

The steps of the Phelps operation are as follows: After proper surgical preparation the Esmarch bandage is applied. The tendo Achillis, and usually the posterior ligament of the ankle, are divided subcutaneously, and by manual or instrumental force the equinus is corrected as far as possible. An incision is then made on the inner border of the foot, just below and in front of the internal malleolus which is extended directly downward over the head of the astragalus to include the inner quarter of the sole. Through the incision all resistant parts are divided, according to Phelps, somewhat in the following order:

1. The tibialis posticus, and the anticus if it offers resistance.
2. The abductor pollicis.
3. The plantar fascia.
4. The flexor brevis digitorum.
5. The long flexor of the toes.
6. The deltoid ligament in all its branches.

During the successive division of the tissues repeated attempts are made to correct the foot, and only those structures are divided that present themselves as tense and resistant tissues when the foot is forcibly abducted.

In the adult type of club foot no attempt is made to recognize the different structures, but all the tissues on the inner side of the foot including blood-vessels and nerves, the deep ligaments, and occasionally the tendon of the peroneus longus muscle, are divided. Even then it is necessary to apply considerable force to correct the deformity (Figs. 2173 and 2174). In rare instances the rectification of deformity necessitates osteotomy of the neck of the astragalus, or the removal of a cuneiform section from the os calcis. The object of the Phelps operation is, by the use of force and by division of resistant tissues, to over-correct the deformed foot at one sitting, and as much force and as extensive division as are required should be employed by the operator.

When the foot can be held in the desired position without resistance, the wound is covered with Lister protective, the foot and leg are thickly covered with gauze and cotton, a plaster bandage is applied, and the limb is elevated. In younger subjects the patient may walk upon the corrected foot in a few days. The large gaping wound closes by granulation in from one to three months; in many instances healing is practically completed under the first dressing.

By this operation the foot, even in severe cases in adult life, may be made straight in appearance. It is evident, however, that in such cases the correction of the deformity of the bones is by no means always perfect, for the fore foot may be simply twisted outward and upward while the astragalus and os calcis may remain in an approximation to their original deformity. After thorough over-correction by the Phelps method the danger of recurrence of deformity in the adult and adolescent type of club foot is not great, and in many instances support other than that of the plaster bandage for several months after the operation may be unnecessary; but in childhood the ordinary precautions in after-treatment to prevent relapse will be necessary.

Operations on the Bones.—Osteotomy of the neck of the astragalus, as a supplementary part of the operation of forcible correction, has been mentioned. In certain instances, particularly in the adolescent or adult type of deformity, the displaced astragalus may offer such an obstacle to correction that its removal is indicated—an operation first performed by Mr. Lund of Manchester.

Astragalectomy.—The astragalus is usually removed by means of an incision passing over its most prominent part, in a direction forward and downward from the tip of the external malleolus, between the tendons of the peroneus brevis and peroneus tertius. The soft parts are drawn aside, the ankle and astragalo-scaphoid joint are opened, and the attachments to the scaphoid, and, as far as possible, those at the inner and outer border, are divided. The foot is next adducted so that the head of the bone may be seized with forceps and drawn upward; the interosseous ligament and the internal lateral ligament may then be divided with curved scissors and the bone may be removed. If after removal of the astragalus the deformity cannot be corrected, the anterior part of the os calcis or the external malleolus should be removed as well. A useful movable foot may be obtained by this operation, but it by no means assures the patient from recurrence of deformity. It is rarely indicated as a primary operation. The varus should be thoroughly corrected as a preliminary procedure; then the resistance that the astragalus offers to dorsal flexion can be estimated.

Cuneiform Osteotomy.—The removal of cuneiform sections of bone from the outer border of the foot is sometimes necessary, but the operation should be secondary to other methods of correction. The aim should be to lengthen contracted and shortened tissues on the inner border of the foot, to the extent required for reposition; not to remove bone to accommodate these shortened tissues. If this has been shown to be impossible by ordinary means, then removal of bone may be indicated, but this is practically never necessary in childhood or even in adolescence. If sufficient bone is removed from the adult foot to allow of perfect correction of the deformity, relapse is not usual; but in childhood, as has been stated, no operation will take the place of after-treatment.

The treatment by cuneiform osteotomy as it is ordinarily carried out is sufficiently simple. In severe cases, the astragalus is usually removed and a wedge-shaped section of bone is taken from the os calcis and the cuboid, and if necessary also from the scaphoid bone. The external malleolus may be removed if it interferes with reposition. Preliminary fasciotomies and tenotomies are usually performed, but those who favor this method of treatment rarely use force in reposition. In less advanced deformity the astragalus is not removed, but a part of its body and neck is included in the cuneiform resection. The foot is retained in proper position until the wounds are closed; then plaster bandages are employed for several months. Braces are seldom used in the after-treatment.

In certain cases of relapsed or ineffectively treated club foot, even in childhood, deformity of the os calcis either interferes with correction of the foot or favors relapse. In such instances the removal of a cuneiform section of bone from the anterior extremity, as a supplementary part of over-correction, may be of service.

Simple Mechanical Rectification of Deformity in Walking Children and in those of Older Growth.—It has been stated that simple mechanical rectification of deformity was possible even up to adolescence, but that the time required for such treatment, usually extending over several years, as a rule excluded it from consideration.

The simplest mechanical treatment is that by which the foot is slowly forced from equino-varus into equino-valgus by a brace on the lever principle, which is at first shaped to the deformity, and is then gradually straightened as the resistance diminishes. When the midpoint has been passed between varus and valgus the weight of the body aids in the correction of the remaining varus and equinus. The modification of the Taylor brace used by Judson, an advocate of pure mechanics in the treatment of club foot, will serve to illustrate the type of apparatus which, with slight change, may be employed to correct or to support the weakened or deformed foot.

The brace consists of an upright, a flat tapering bar of mild steel, a foot-plate of steel from 18 to 16 gauge, and a strong calf-band. The shape of the brace, the method of its attachment to the legs by straps of webbing, and its effect in gradually changing the attitude of the foot from varus to valgus are shown in the accompanying figures (Figs. 2174–2181).

The upright is firmly riveted to the foot plate in the angle of deformity, so that the patient walks upon his toes; as the equinus is decreased by the influence of the weight of the body, this angle is lessened.

The important points are, that the brace should be strong enough to hold its place under the strain of use, and that the foot shall be firmly secured to it, whether one or many straps of webbing are required, as may be seen in the figures. The use of massage and manipulation is of course combined with the mechanical treatment.

By persistent attention to the details of treatment satisfactory results can be obtained by this method in the less resistant cases, even in adolescence.

Recapitulation of the Principles of Treatment of Congenital Talipes Equino-Varus.—The object of treatment is to overcome and to over-correct the deformity at as early a period of life as is possible, and as quickly as possible. The object of over-correction is to overcome all the resistance of the tissues that may even in the slightest degree limit the normal range of motion in any direction. The foot must be supported in the over-corrected position until the recoil of the tissues toward deformity is no longer present.

It must be supported in the proper relation to the leg, and at a right angle with it, until the muscular balance has been re-established by stimulation of the weaker, and by limitation of the activity of the stronger, muscles, and until transformation of the internal structure has been completed.

If efficient mechanical treatment is applied at the proper time, that is to say, in earliest infancy, no operation, other than division of the tendo Achillis, will be required.

If the deformity is not corrected or is but partially corrected, when the child has begun to walk, some form of operation is as a rule indicated; but division of the resistant tissues must always be combined with the employment of sufficient force to accomplish the desired result, viz., over-correction of the deformity. Manual correction, applied in the manner described, is the most efficient means of attaining this object. No instrument can equal the hand, and the force that can be applied by the hand is sufficient in all the ordinary cases in early childhood, and in combination with subcutaneous division of the more resistant tendons and ligaments, even in later childhood and adolescence.

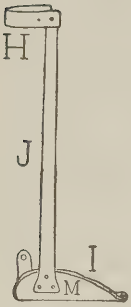

FIG. 2175.

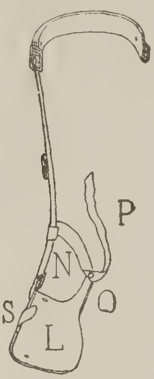

FIG. 2176.

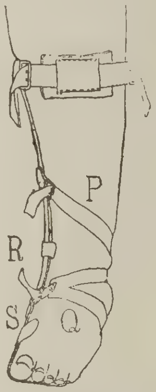

FIG. 2177.

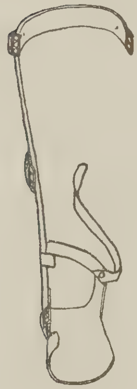

FIG. 2178.

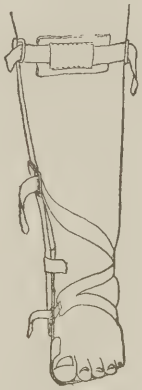

FIG. 2179.

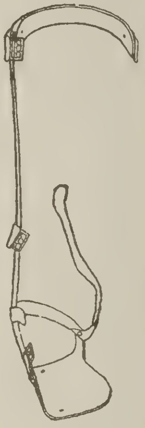

FIG. 2180.

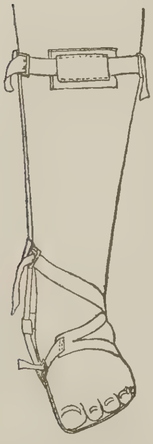

FIG. 2181.

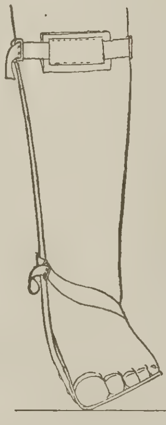

FIG. 2182.

Forcible correction by the Thomas wrench under the same conditions is an efficient treatment, but there is a manifest disadvantage in submitting a patient to a succession of operations, even of so slight a character, if immediate over-correction can be attained by other means.

The Phelps' operation, which combines thorough division of the resistant parts with the application of proper force to over-correct the foot, is the operation of selection for the more resistant cases in adolescence, in adult life, and in extremely resistant cases in childhood.

Astragalectomy and cuneiform resection are never indicated as primary operations, but one or the other may be necessary in the rectification of the deformity when other means have failed.

Complete cure of deformity, even in the later years of childhood, is possible by means of braces alone, but such treatment is very tedious. It requires not only the continuous supervision of the skilled surgeon, but the intelligent and persistent co-operation of the parents. The results are in no way superior to those attained by more rapid methods, while the disadvantages of long-continued use of braces are sufficiently obvious. To the popular faith in braces as a cure-all of deformity, and to the unintelligent use of braces, may be ascribed, now as in former times, the failure of treatment of this eminently curable deformity. This statement seems justified, even when balanced by the equally fallacious belief, so prevalent among physicians, that an operation, if not synonymous with cure, is, at least, the essential part of the treatment.

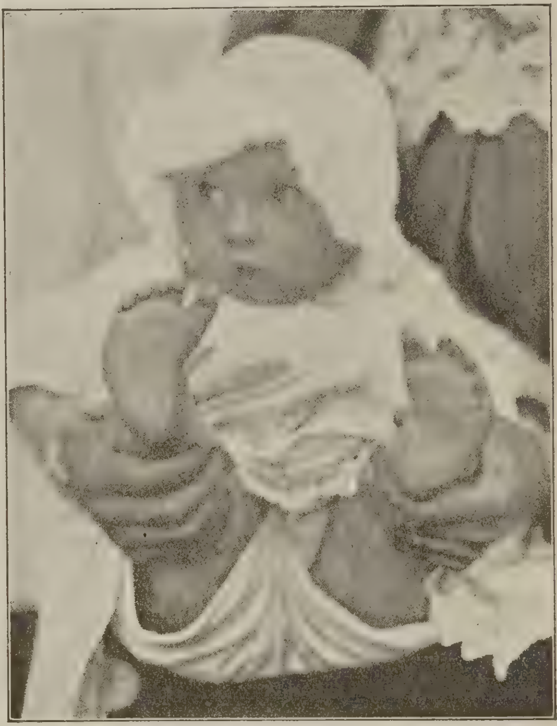

FIG. 2183.—Congenital Talipes Varus.

Rectification of deformity, by whatever means, simply completes the first stage of treatment. Perfect cure can be assured only by attention to the small details of after-treatment, by checking the slightest impulse toward deformity, and by guiding the unbalanced foot toward perfect functional use.

OTHER VARIETIES OF CONGENITAL TALIPES.—Forms of congenital distortion of the foot other than equino-varus are not uncommon, but as a rule these deformities are so slight, and, as compared to equino-varus, so easily remedied that they are relatively of little importance (Fig. 2183). This distinction does not apply, however, to acquired talipes, of which the various forms will be considered in other sections.

Congenital Talipes Varus.—This deformity often appears to be an incomplete form of equino-varus, but in some instances there is simply a slight inward twist of the foot without supination; in fact, the fore foot seems to be drawn inward by the active movement of the great toe, which in such cases seems almost prehensile (see Pigeon Toe). In the more marked form the foot is adducted and supinated, and the tissues are very resistant.

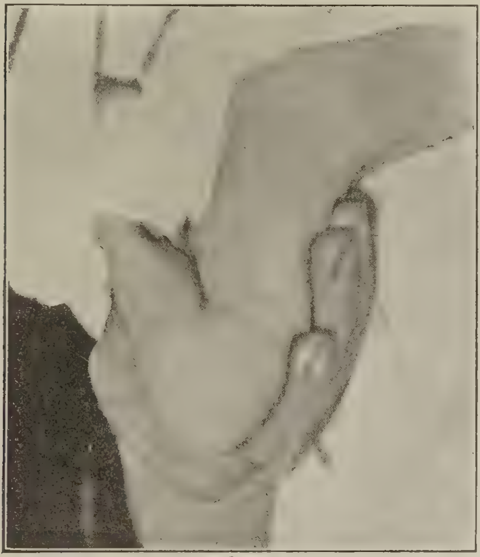

FIG. 2184.—Congenital Talipes Calcaneus.

The slight grades of deformity may be treated by simple manipulation, and if deformity remains after the first year, the shoe will, as a rule, correct it. The more marked varieties must be treated like the varus deformity of club foot, until the varus has been transformed into valgus. The after-treatment is the same as that for ordinary club foot.

Congenital Talipes Equinus.—This is a rare congenital deformity, about half as common, according to the statistics, as varus (40 cases in 1,660). The term equinus implies that dorsiflexion is limited, but that the foot is not deviated to one or the other side (toward valgus or varus). In congenital equinus the deformity is as a rule slight, and it may be overcome usually by simple manual force applied frequently. In the more resistant type, mechanical correction, or tenotomy, followed by over-correction and support, may be necessary.

Congenital Talipes Calcaneus.—Congenital calcaneus is comparatively rare (28 cases in 1,660). As a rule the heel is prominent, the foot is habitually dorsiflexed, and the dorsum can be brought into contact easily with the crest of the tibia (Fig. 2184). The exaggerated cavus that is usually present in acquired calcaneus is absent. Occasionally the deformity is accompanied by hyperextension of the knee, and if, as in many instances, there is a history of breech presentation, it may be inferred that the attitude before birth was one of extreme flexion of the thighs upon the abdomen, while the anterior surfaces of the extended legs were pressed closely to the ventral surface of the body, the feet being fixed in an attitude of dorsiflexion. As a rule the deformity is slight, and the resistance of the tissues on the anterior aspect of the leg can be overcome easily by massage and manipulation. The foot should be gently forced toward plantar flexion several times in the day, and the weak muscles of the calf should be stimulated by massage.

Cure may be hastened by the use of some simple form of retention splint to hold the foot in plantar flexion until the posterior group of muscles has recovered its power. Tenotomy or other operative treatment is not often necessary. In rare instances, the tibia may be bent slightly backward, thus increasing the deformity. In such cases the distortion of the bone may be overcome by manipulation and by apparatus.

Congenital Talipes Valgus.—Congenital valgus is somewhat more common than the preceding varieties (123 in 1,660). Not infrequently it is combined with a slight degree of calcaneus or equinus. The resistance of the contracted tissues is not great and the deformity may be overcome, in most cases, by persistent manipulation. If the muscular power is sufficiently unbalanced to warrant it, the foot should be held in the over-corrected position (varus) for some time.

Congenital valgus is one form of what is known as weak ankle, and it frequently passes unnoticed until the child begins to walk. If at that time, in spite of massage, the muscles appear weak or the foot inclines outward when weight is borne, it is well to make the sole of the shoe wedge-shaped, the thicker part (one-quarter of an inch) on the inner side. In more persistent cases, a brace may be necessary, as described in the treatment of the acquired variety (see the Weak Foot).

Talipes equino-valgus is less common. This must be treated as the other varieties by complete over-correction of deformity, manual or otherwise, by massage, and subsequently by support if necessary.

Calcaneo-valgus, calcaneo-varus, equino-cavus, valgo-cavus, valgo-cavus and cavus are extremely rare. If treated early by persistent forcible massage, these, as well as nearly all slighter grades of congenital deformity, may be corrected or cured even, before the child begins to walk.

CONGENITAL DEFORMITIES OF THE FOOT ASSOCIATED WITH DEFECTIVE DEVELOPMENT.—*Talipes Equino-Valgus Associated with Congenital Absence of Fibula.*—This is a rare deformity, but the most common of this class. The foot at birth is usually in an attitude of well-marked and resistant equino-valgus. The leg is somewhat shorter than its fellow, and the tibia is often bent sharply forward, sometimes to an acute angle, at a point somewhat below the centre, as if it had been broken in utero. At the most prominent point the skin may be adherent or it may present a dimpled appearance. In some instances the formation of the foot is perfect, but more often one or more of the outer toes, with the corresponding metatarsal bones, are absent.

The cause of deformity associated with absence of bone must be either an original defect in the germ or it may be due to interference with its development. In some instances amniotic adhesions may be one of the predisposing causes; the sharp bend in the tibia, so often present, may be due to lessened resistance of the defective part.

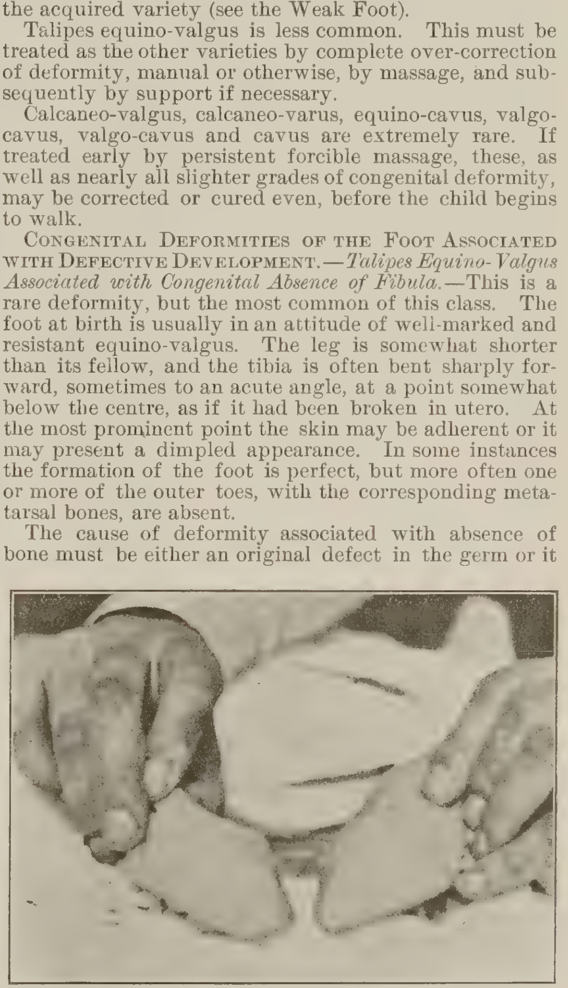

FIG. 2185.—Congenital Talipes Valgus—"Flat Foot."

Treatment.—The indications for treatment are to correct the deformity of the foot in the usual manner. The bend in the tibia may be straightened by manipulation and splinting, or by osteotomy if necessary. When the patient begins to walk the foot must be supported. A light steel upright on the outer side of the leg, provided with a T strap to hold the ankle against it, may be used to supply the place of the missing fibula. The growth of the tibia is retarded, and a final shortening of three or more inches may be expected, but with care a useful limb may be assured.

Talipes Varus or Equino-Varus Associated with Congenital Absence of the Tibia.—Defective formation of the tibia is much less common than that of the fibula. In most cases the femur is somewhat shortened and its lower extremity is imperfectly developed. The foot is practically always in an attitude of varus. The toes may be normal, but in a number of instances one is found to be lacking.

The prognosis, as regards a useful limb, is extremely bad. The growth of both the thigh and the lower leg is much retarded, and it is almost impossible to balance the foot upon the fibula by any form of brace.

The ordinary treatment, after the correction of the deformity of the foot, has been to resect the extremities of the femur and the fibula to produce ankylosis between the bones. No final results have been reported. A full account of the reported cases may be found in an article by Launois and Kuss, *Revue d'Orthopédie*, September, 1901.

Deformity of the Foot Associated with Absence of Bones.—The leg bones may be perfectly formed, but one or more bones of the foot itself may be absent. In these cases, after the reduction of the deformity, a support to hold the defective foot in its proper relation to the leg must be used.

The foot may be divided into two parts so that it resembles a lobster claw. Supernumerary toes, or deficiency of toes, or hypertrophy of one or more of the toes, with or without corresponding overgrowth of the foot or leg, are not extremely uncommon. These deformities must be treated on ordinary surgical principles.

Constricting Bands.—Tightly constricting bands of scar-like tissue, which cause deep indentations in the flesh of the foot or leg, are sometimes seen. These are supposed to be caused by amniotic adhesions. "Spontaneous amputations" of toes, or of the foot itself, are due to the same cause.

In ordinary cases the bands require no treatment, but they interfere with the nutrition of the foot. They may be removed.

Congenital Œdema of the Feet.—In rare instances, sometimes in combination with deformity, the tissues of the feet appear to be œdematous, although the circulation seems to be perfect. The condition is apparently due to obstruction of the lymphatic circulation. It should be treated by massage and compression.

Spina Bifida and Talipes.—Talipes coexisting with spina bifida should be treated as are other forms of club foot. If paralysis of the lower extremities be present, as is often the case, the corrected feet must be supported as in the ordinary forms of paralytic deformity.

ACQUIRED TALIPES.

It has been stated that equino-varus is by far the most common of the congenital deformities of the foot and that as compared with it the other forms of talipes are of slight importance.

In the acquired varieties of talipes, equino-varus is much less common (32.5 per cent. of the total number as contrasted with 77 per cent. of the congenital deformities). Acquired equinus comes next in frequency (26 per cent. as compared with 2.4 per cent. of the congenital deformities), and every variety and combination of distortion finds its representative in acquired talipes as may be seen in the table of statistics.

Etiology.—The cause of acquired talipes is almost always paralysis. In the table of statistics it may be noted that in 82.8 per cent. the paralysis was of spinal origin (anterior poliomyelitis); in 11.3 per cent. the lesion was of the brain, the talipes being a part of the deformity of hemiplegia or paraplegia. A few cases were caused by local disease of the nerves, and the remainder, 5.4 per cent., were of traumatic origin.

The distinction between congenital and acquired talipes is well marked. In the congenital form the disability is due simply to local deformity, and when this has been overcome a perfect cure may be expected. In paralytic talipes the rectification of deformity is but a part of the treatment, and perfect cure is impossible except in that small proportion of cases in which the spinal cord has sustained no permanent injury, or in which the deformity was the result of some slight or passing disability or disease.

Congenital deformity cannot be anticipated or prevented; acquired deformity is an evidence that protective treatment has been neglected. It is a result, therefore, that may be foreseen and prevented.

The characteristics of anterior poliomyelitis are described elsewhere. In its effect upon the foot the usual sequence is somewhat as follows: Immediately after its onset the paralysis is usually widespread, affecting the entire limb, for example. Then follows a period of partial recovery, after which the amount of damage that the spinal cord has sustained may be estimated. It is during the period of partial recovery, the six months or more following the attack, that contractions which lead to deformity occur. If, for example, the anterior group of leg muscles is paralyzed, the foot habitually hangs downward, a position due to the force of gravity and to the contraction of the unaffected posterior group. If this attitude is allowed to persist, the tissues accommodate themselves to the new position; the muscles that are never extended to their normal limit become structurally shortened, while the paralyzed group becomes correspondingly longer. Even within a few weeks after the onset of the paralysis the evidences of advancing deformity appear. The contracted tissues resist passive motion in the direction opposed to the habitual attitude, and the child shows evidence of pain if force is used to increase the limited range of motion. As has already been stated, paralytic talipes is an unnecessary deformity. It may be prevented by supporting the paralyzed part in a right-angled relation to the limb, and by systematic passive exercise throughout the entire range of normal motion.

Anterior poliomyelitis is most common during and after the second year of life or when the child has already begun to walk. When the first and more general effect of the disease has passed away, the child again uses the disabled limb as best it may; thus the distortion of the foot is increased and confirmed by the weight of the body and by functional use in the abnormal attitude.

The final deformity in a particular case may be predicted from the knowledge of the function of the muscle or muscles which has been lost. For example, paralysis of the tibialis anticus, the most powerful dorsiflexor and adductor of the anterior group, must result in equino-valgus; paralysis of the tibialis posticus induces valgus. If the peroneus brevis and tertius are affected varus will follow. Paralysis of the calf muscle will cause calcaneus. Paresis or paralysis of the entire anterior group will cause equinus. If all the muscles are paralyzed, what is called a "dangle foot" is the result. The cold atrophied member dangles from the attenuated leg with but little tendency to deformity unless the limb is used, when it is usually forced into an attitude of equino-varus or valgus.

A slight degree of paralysis may cause so little disability that it may be entirely overlooked, and its later effect in causing disability or deformity may not attract attention for many years. This fact has been mentioned in the etiology of the contracted foot.

Differential Diagnosis between Congenital and Acquired Deformity.—The history itself is usually sufficient, for deformity of the foot at birth is never overlooked by the mother. Acquired talipes is practically always preceded by a history of disease, or weakness, or injury which was soon followed by slight and afterward by increasing and confirmed deformity.

In paralytic talipes (anterior poliomyelitis), there is evidence of paralysis in loss of function of certain muscles, as shown by electrical stimulation or by pricking the foot with a pin; later, in the atrophy of the muscles, and the evident change in the nutrition and diminished growth of the limb.

Only in extreme and untreated cases of congenital deformity of long standing could there be difficulty in distinguishing between the acquired and the congenital deformity. In rare instances, it is true, paralysis may be present at birth, due to intra-uterine disease or to defect in the nervous apparatus. In such cases the cause of the paralysis is usually apparent (spina bifida, or spastic paralysis associated with defective cerebral development), and the treatment does not differ from that of the acquired form.

ACQUIRED TALIPES EQUINUS.

In well-marked cases, the foot is plantar-flexed to its full limit, and it is held in this attitude by the shortened structures on the posterior aspect of the leg. The patient walks upon the heads of the metatarsal bones, the toes being dorsiflexed to accommodate the attitude. The arch of the foot is increased and the tissues of the sole, particularly the plantar fascia, are contracted. The entire foot is broadened and shortened, the breadth being especially increased across the metatarsal region. On the dorsal surface the cuneiform bones are prominent, and the head and body of the projecting astragalus may be felt beneath the skin. Occasionally, in cases of extreme deformity, in which all the anterior muscles are paralyzed, the toes may be plantar-flexed so that the patient walks upon their dorsal surface.

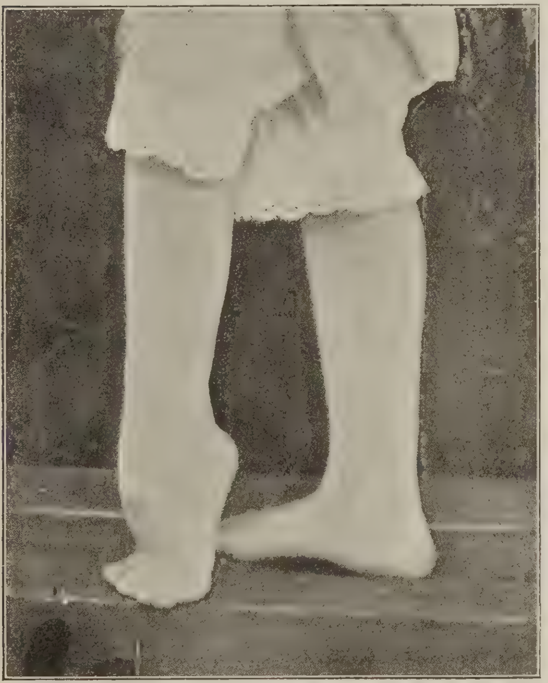

FIG. 2186.—Acquired Talipes Equinus.

The cavus or exaggerated arch is due primarily to the plantar flexion of the fore foot at the medio-tarsal joint, and in many instances this dropping of the fore foot is largely responsible for the equinus, for the os calcis is rarely plantar-flexed to the degree commonly found in the ordinary congenital equinus.

In the slighter degrees of the deformity the toes are usually dorsiflexed, an attitude due apparently to the over-action of the extensor longus digitorum and proprius pollicis, an aid in dorsiflexion.

Etiology.—Equinus in the slighter degrees is perhaps the most common of the forms of acquired talipes, and it is not at all infrequent as a result of other affections than anterior poliomyelitis, although this is by far the most important cause. The nerve supply of the anterior muscles of the foot seems especially susceptible, and toe-drop from neuritis of various types is not at all uncommon. As a sequel of infectious diseases it has been mentioned as an explanation of the slight forms of equinus first noticed after recovery from such affections.

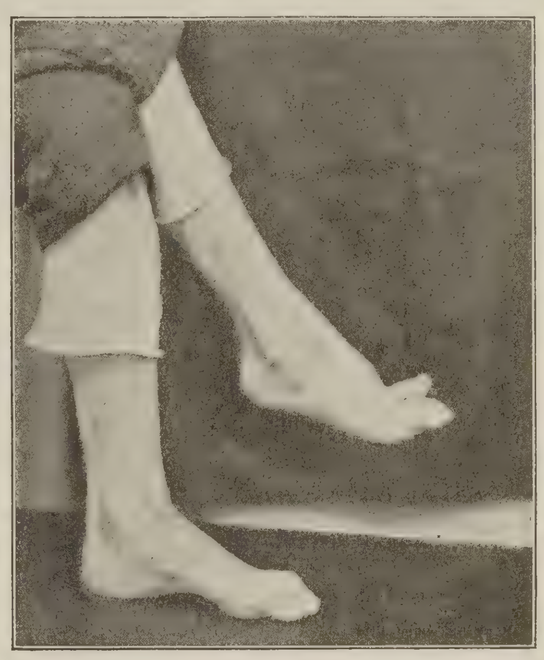

FIG. 2187.—Slight Equinus Caused by Paralysis of the Tibialis Anticus Muscle. The distortion of the toe due to the over-use of the extensor proprius pollicis is characteristic.

Equinus may be a result of cerebral disease, or even, in rare instances, of pseudo-hypertrophic muscular paralysis or of locomotor ataxia. It is sometimes induced by habitual posture, as after long confinement to the bed for the treatment of fracture, or during the treatment of hip disease by apparatus. The contraction may be an effect also of voluntary posture as when the patient habitually walks upon the toes because of a short leg. It is a very common result of neglected disease at the ankle joint, and it may be due to direct injury; but as of paralysis, so of these less frequent causes it may be said that equinus need never follow, if the foot is protected.

The changes in the internal structure of the foot are secondary to the deformity and are more marked in the cases of long standing originating in early life than in those that follow other forms of deformity; the tissues on the long side are lengthened and attenuated while those on the short side become contracted. The bones themselves are but little changed in gross appearance, but the articulating surfaces are in different relation to one another; for example, only the posterior aspect of the astragalus is in relation to the tibia, while only the lower part of its anterior surface articulates with the scaphoid bone.

In all cases of equinus there is a strong tendency toward lateral deviation to varus or valgus, particularly in cases of paralytic origin.

Symptoms.—If the limb is actually shorter than its fellow, and if the foot is firmly fixed in the deformed position, surprisingly little discomfort or disability may be experienced other than from corns or calluses beneath the metatarsal bones. If the limb is not shorter, the additional length caused by the equinus must be compensated by an upward tilting of the pelvis, which may induce symptoms of discomfort in the lumbar region. The gait is always awkward, giving the impression as of stepping over an obstacle. If the foot is not fixed but simply hangs downward when it is lifted, the gait is very awkward because of the insecurity and because of the exaggerated flexion of the knee at each step, necessary in order that the pendent foot may not drag upon the ground.

If the equinus is extreme, the limb is usually flexed at the knee when in use; if the equinus is slight, the strain resulting from the limitation of dorsal flexion is felt at the knee, and in childhood at least there is often a well-marked tendency to over-extension, or recurvation, caused by the effort to place the sole flat on the ground.

In the slight forms of equinus, discomfort about the calf is experienced; the limitation of dorsal flexion causes a rather shortened stride and awkward gait, while an unguarded step that throws a sudden strain upon the rigid heel cord is felt as a shock and strain through the leg and body. Very often the patient complains of pain about the metatarsal bones (anterior metatarsalgia), and if the equinus is accompanied by a slight degree of valgus, symptoms of the weak foot may be present.

The *Prognosis* depends of course upon the cause of the deformity. If it is simply the result of posture, or if it is secondary to neuritis, permanent cure may be expected. In many cases caused by anterior poliomyelitis recovery of function, complete or partial, has taken place; yet although voluntary control of the muscles has been regained it cannot be exercised because the foot is held in the distorted position by the contracted tissues.

In such instances practical cure may be predicted if, after the over-correction of deformity, sufficient time is allowed for the lengthened and atrophied muscles to regain their proper length and volume.

Treatment.—In the somewhat uncommon cases of fixed equinus combined with a short leg and not attended by discomfort, no treatment is required other than a shoe so built that the heel may support a part of the weight. In the more extreme cases in which the leg is short and the foot is atrophied, an extension foot attached after the manner of an artificial leg may be worn with comfort and with but little evidence of deformity.

In the ordinary cases, whether permanent cure is expected or not, the rule holds good that the heel should bear the weight of the body and that the range of dorsal flexion should not be limited when the calf muscle retains its power. If the nervous apparatus has received permanent injury, the foot must be supported after the deformity has been rectified; but even in this class the gait may be improved and the discomfort relieved by removing the restrictions to normal motion. The slighter degrees of equinus, such as those that are seen soon after the onset of anterior poliomyelitis, may be rectified by simple manipulation and retention in a splint or in plaster of Paris.

The Shaffer extension shoe is also a useful appliance, and is especially so in that it may be employed to reduce the accompanying cavus at the same time.

The weight of the body may be utilized as a means of overcoming slight equinus, when the foot is held in its proper relation to the leg by a brace which extends above the knee; but this tedious method has but little to recommend it in ordinary cases. The elastic tension of straps and bands attached to a brace or to the foot itself by means of adhesive plaster is of some service in slight cases, but by far the most effective method is the immediate reduction of the deformity by a simple forcible manipulation under anæsthesia, or by tenotomy combined with forcible manipulation, or by wrenching.

Immediate Correction of Deformity.—Attention has been called to the cavus as an accompaniment of confirmed equinus, and whenever one attempts to correct the deformity by force, the exaggerated arch should be reduced to its normal depth, otherwise the foot will appear stunted and deformed.

One of the most effective procedures for overcoming the cavus is the use of the Thomas wrench. The contracted bands of the plantar fascia are first divided subcutaneously, the wrench is then fixed to the foot, and, with sudden force exerted against the resistant tendo Achillis, the foot may be straightened, the deep ligaments being ruptured or stretched to the proper degree. The tendo Achillis is then divided, and the foot having been dorsiflexed is fixed by a plaster-of-Paris bandage. As the patient is encouraged to walk upon the foot as soon as possible, the weight of the body forcing the relaxed tissues against the unyielding sole, completes the flattening of the arch. In many of these cases the knee has been over-extended by use in the deformed attitude, so that the habitual flexion necessary to bring the dorsiflexed foot upon the ground during the two months allowed for the complete union of the divided tendon is of benefit as it serves to correct this secondary weakness and deformity.

The importance of the immediate relief of the strain of the deformed position upon the weak anterior group of muscles, together with the complete relaxation of the over-stretched tissues which allows the "slack to be taken in" during the long rest in the over-corrected position, is not generally appreciated. Whenever the weakened muscles after paralysis show by tests, electrical or otherwise, that they have recovered their power in part, this treatment should be that of selection. The application of electricity or other form of stimulation to muscles that are unable to exercise their function because of contraction of opposing tissues is useless. Nor is any form of artificial stimulation equal to that of the functional use, which is made possible by the removal of the deformity and by the employment of proper support.

In many instances after the equinus, which more often than any other deformity is the result of slight or temporary disability of the anterior group of muscles, has been corrected in the manner described perfect cure seems to have been attained when the plaster bandage is finally removed. But even in such cases the application of a simple support to hold the foot at a right angle with the leg for several months is an advantage. The after-treatment by massage, muscle-beating, electricity, and the like, combined with methodical passive movements to the limit of dorsal flexion to guard against recontraction of the calf muscle, should be continued for a long time, or until the muscular balance has been regained.

The same form of support is necessary in cases of hopeless paralysis, to hold the foot at a right angle with the leg. The common form is a simple steel sole plate of sufficient size to support the foot and the toes, if their muscles are paralyzed, attached to a light upright provided with a calf band. The upright is usually applied on the inner side of the leg where it is least noticeable. At the ankle there is a "stop joint," which allows dorsiflexion but prevents the toe-drop. This, when properly fitted, can be placed inside the ordinary shoe, as the paralyzed foot is usually somewhat smaller than its fellow. If the toes do not need support, the upright can be attached to the outside of the shoe and the foot plate may be dispensed with; or the upright may be concealed by introducing it inside the shoe to a joint sunk in the heel; the toe-drop being prevented by straps passing from the front of the upper leather of the shoe to the calf band.

Equinus due to posture or disease may be cured by simple correction of the deformity. That due to fracture, when the deformity is caused by displacement of the bones, may be treated by direct operation or by the removal of a cuneiform section from the anterior surface of the tibia above the ankle.

ACQUIRED TALIPES CALCANEUS.

Acquired talipes calcaneus is much less frequent than equinus and it is almost always of paralytic origin (anterior poliomyelitis).

There are several varieties or grades of the deformity. In the early stage, and especially if all the muscles of the posterior group have been paralyzed, the foot assumes an attitude of slight dorsiflexion and the range of plantar flexion is gradually lessened by secondary contractions. This variety resembles closely the congenital form. In the ordinary and typical form of calcaneus, when fully developed the patient walks, as the name implies, on an elongated heel. The arch of the foot is much increased in depth, and the fore foot is atrophied and useless.

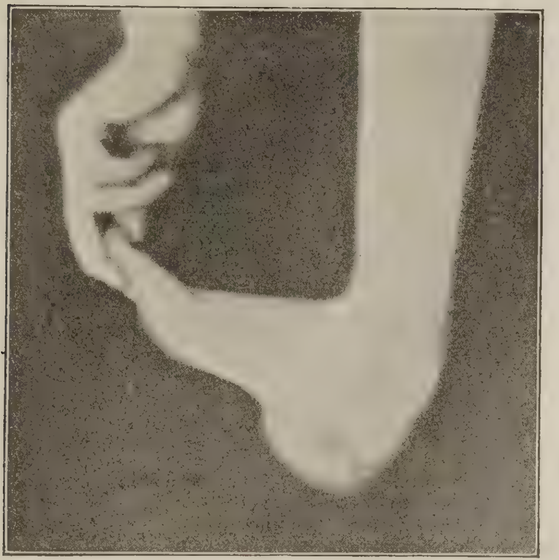

FIG. 2188.—Acquired Talipes Calcaneus.

The development of the deformity is somewhat as follows: The support of the calf muscle being removed, the os calcis, in the foot that is used, gradually assumes an attitude of dorsiflexion. It stands on end so that its posterior surface becomes inferior. The posterior projection of the heel is lost and it lies in the plane of the atrophied calf. The change in the position of the os calcis increases the distance from the malleoli to the ground; thus calcaneus, though in less degree than equinus, makes the leg longer. The turning of the os calcis on end shortens the foot and increases the arch; thus cavus in more marked degree than with equinus accompanies calcaneus. The cavus is a later complication of nearly all cases of paralytic calcaneus. In many instances there is no permanent dorsiflexion or elevation of the forefoot, although in all the range of plantar flexion is limited. In this class the power in the remaining muscles of the posterior group is probably sufficient to counteract the contraction of the dorsiflexors. Cavus is thus a direct effect of the displacement of the os calcis. If the entire posterior group of muscles is paralyzed, while the anterior muscles are unaffected, the foot will be somewhat dorsiflexed and the cavus will be less marked. If the calf muscle only (gastrocnemius and soleus) is paralyzed, the remaining muscles of the posterior group will counterbalance the dorsiflexors and at the same time increase the cavus. In some instances the calf muscle is alone affected, in others one or more of the anterior muscles may be paralyzed also, in which case the foot is usually turned toward varus or valgus. The changes primarily caused by the paralysis and by unopposed muscular action become fixed by habitual use and by secondary adaptation of the tissues. The heel only is used in walking, and the area of callus which marks the weight-bearing surface becomes much enlarged, while the fore foot and toes, which have but little functional use, become atrophied, a mere appendage to the enlarged heel.

Symptoms.—The gait is awkward and inelastic; the patient, who is, as it were, "ham-strung," stamps along upon the insecure support of the heel in a manner which is easily recognizable by one familiar with the disability. The changes in the internal structure of the foot, the inevitable adaptations to the deformity, do not call for especial description; the disused bones atrophy together with the other tissues and new articulating surfaces form to accommodate the necessities of functional use.

Treatment.—When the diagnosis of paralysis of the calf muscle is made one may predict, unless recovery takes place, a deformity such as has been described. This deformity may be prevented by proper support, by massage, and by methodical stretching of the tissues that have a tendency to contract. The form of brace used for walking and for support should be provided with a sole plate, upright, and calf band, as already described in the treatment of paralytic equinus. If motion is allowed at the ankle it should be in plantar flexion only, the stop being the reverse of that used in equinus, or as this form of check entails much strain upon the brace, the joint may be omitted as in that form used by Judson. Thus the strain removed from the weakened tissues is borne by the anterior surface of the leg. Other forms of braces provided with elastic bands to supply the place of the calf muscle are sometimes used, but as a rule the improvement in gait hardly compensates for the trouble in adjustment or the conspicuousness of the appliance.

The most important part of the actual deformity of calcaneus is the cavus due to the changed position of the os calcis; and in confirmed cases it is practically impossible to reduce this completely because the absence of the tendo Achillis takes away the point of resistance that makes the corrective force efficient. If the deformity is not marked operative treatment is not required. The foot may be drawn as far as possible toward equinus and fixed in a plaster bandage. Upon this the patient may walk, the heel being built up with cork wedges to make the sole level. When the contraction of the anterior tissues has been overcome, the brace is applied and the usual treatment of manipulation and massage is continued.

The method of prolonged fixation in the attitude of equinus by means of the plaster bandage is often very efficacious in childhood and cures of apparently hopeless cases by this means have been reported.

Operative Treatment.—In more extreme cases immediate reduction of the deformity under anæsthesia may be attempted. The plantar tissues, more particularly the plantar fascia, may be divided and by forcible manipulation or wrenching the foot may be somewhat lengthened and the heel pushed somewhat upward and backward, so that the foot may be fixed in a plaster bandage in slight plantar flexion. The tissues on the front of the leg that require elongation are those directly in front of the ankle. It must be borne in mind that in correcting the deformity one must not force the forefoot downward, as this would simply increase the cavus, but whatever overcorrection is gained should be by means of elevation of the os calcis and elongation of the plantar tissues.

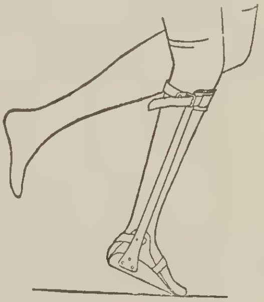

FIG. 2189.—Judson's Brace Applied for Talipes Calcaneus.

In some instances the improved position of the os calcis may be confirmed by shortening the tendo Achillis, as first performed by Willett, of London (St. Bartholomew's Hospital Reports, vol. xvi., 1880, p. 309).

Willett's Operation for Calcaneus.—A Y-shaped incision about two inches in length is made through the tissues down to the tendon. At the lower or vertical part of the incision, which is continued down to the tuberosity of the os calcis, the tendon is dissected free from the surrounding parts. It is then divided in an oblique direction from within outward and downward, and the heel having been pushed upward as far as possible, the divided ends are overlapped and sutured; the flap of skin is drawn downward at the same time, so that the Y incision is converted into the shape of a V. According to Mr. Willett's original directions, deep sutures are passed through the skin flaps and through the tendon on either side, so that all the tissues are united. The foot is then fixed in a plaster bandage, in the attitude of equinus, and the patient is allowed to walk about wearing a high heel to compensate for the elevation of the sole.

The operation is of especial value in those cases in which some power remains in the calf muscle, which is thus made serviceable. In cases of complete paralysis the position of the foot may be temporarily improved, but unless proper support is used afterward, the tissues will stretch under the strain of use; thus the treatment should always be supplemented by a brace of the character already described.

Astragalectomy and Backward Displacement of the Foot.—In cases of confirmed calcaneus, or calcaneus especially if combined with lateral deformity, removal of the astragalus may be indicated. This operation permits the malleoli to be brought into direct contact with the os calcis, thus improving the security of the foot.

The astragalus may be removed by a long curved external incision passing from the tendo Achillis just below the outer malleolus to the front of the joint. The peronei tendons are divided, the foot is displaced inward, and the astragalus is removed. The articulating surfaces of the leg bones and of the os calcis are denuded of cartilage; the tendo Achillis is shortened and to its insertion the peronei tendons are attached, if the muscles are active. The entire foot is then displaced backward so that the denuded malleoli overlap the anterior extremity of the os calcis. The object of this procedure is to throw the weight of the body upon the centre of the tarsus; thus the deformity is reduced and the stability of the foot is increased.

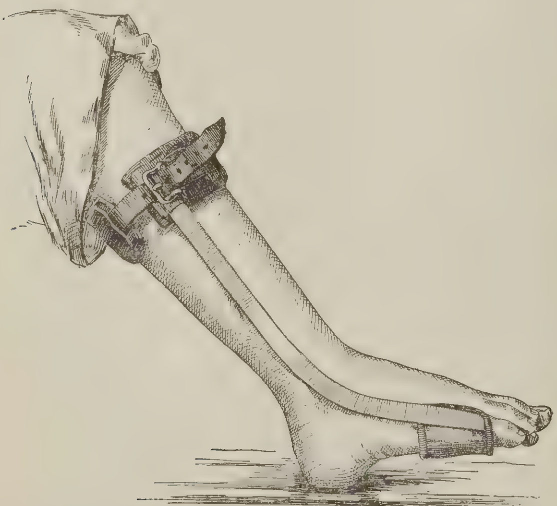

FIG. 2190.—Whitman's Brace for Talipes Calcaneus. Two lateral bars of thin steel connected by a foot plate and anterior leg band. The brace is supported by the shoe which should be elevated sufficiently at the heel to hold the foot in slight equinus.

The wound is closed and the foot is fixed in plaster of Paris. As soon as possible the patient uses the foot in standing and walking. Ultimately apparatus may be dispensed with, but a brace may be used for a time with advantage. This operation has been performed in many instances by the writer, for whom it is now the treatment of choice in this type of cases. By it the usefulness of the foot is greatly increased and its appearance very much improved.

ACQUIRED CALCANEO-VALGUS AND CALCANEO-VARUS.

In many cases the foot deformed as a result of paralysis of the calf muscle is in addition turned in a lateral direction, so that the weight of the body falls to the inner or outer side of its centre.

Calcaneo-valgus, in which the foot is turned outward and upward so that the patient walks on the inner side of the heel, or even on the inner ankle, is not uncommon; the opposite deformity is far less so. Calcaneo-valgus is usually a result of more extensive paralysis than simple calcaneus. For example, all the muscles about the foot may be disabled except the peronei, or in cases of a milder type the tibialis anticus may be the only muscle of the front of the foot that is paralyzed.

Treatment.—When the foot inclines toward calcaneo-valgus it is difficult to hold it in proper position. The usual method is to apply the brace used for ordinary calcaneus, with the upright on the outer side of the foot; the ankle and arch are then held against it by means of the valgus strap. Another form of brace is provided with an upright on either side of the leg, the outer being slightly longer than the inner so that the sole plate is tilted inward, or as it were supinated; thus the weight is guided toward and balanced on the outer side of the foot. It must be borne in mind that other muscles of the limb are often paralyzed, so that the deformity of the foot may be but a part of more general distortion; hence the foot brace is often combined with apparatus for the support of the leg.

In these cases the deformity may be reduced and the stability of the foot may be increased by the removal of the astragalus in the manner described.

Calcaneo-varus is a much less serious affection, since the foot may be more easily supported. A brace such as is used in the treatment of ordinary varus, without motion at the ankle or provided with a reverse stop, is ordinarily employed.

ACQUIRED TALIPES EQUINO-VARUS.

Talipes equino-varus is, as in the congenital form, the most common of the paralytic deformities of the foot.

The tendency of simple equinus is usually toward varus, because in plantar flexion the foot is slightly adducted, and because the outer side of the foot is shorter than the inner side, so that in walking with the foot extended the tendency of the foot is to turn somewhat inward.

Equino-varus is usually preceded by equinus and the etiology of the one will serve for the other.

In certain cases the varus is more marked than the equinus, as, for example, when the abductors of the foot are paralyzed while the adductors retain their power; or in cases of direct injury as in fracture at the ankle; or when the growth of the tibia has been arrested as the result of injury or disease.

The appearance and effect of the deformity are sufficiently indicated in the description of the congenital form.

Treatment.—If the distortion is recent and therefore non-resistant, the treatment consists in supporting the part in proper position by a brace, of which the Taylor club-foot apparatus is the type. During the night the over-corrected attitude may be assured by a strap running from the upright to the sole plate. Massage, electrical stimulation, and the like may be applied as in the routine treatment of anterior poliomyelitis.

If the deformity is fixed it should be reduced and over-corrected by forcible manipulation under anæsthesia. Division of the resistant parts is less often necessary than in the congenital form, but should be performed in suitable cases. The over-corrected position should be retained until time has been allowed for the recontraction of the lengthened tissues, preferably for several months; such rest in the over-corrected position is by far the most effective treatment that can be applied to a weak or paralyzed part.

Astragalectomy and cuneiform osteotomy are rarely indicated, but the latter operation is sometimes of service in checking the tendency toward recurrence of deformity which is more marked after over-correction in the paralytic than in the congenital talipes.

Acquired Talipes Equino-Valgus.

Simple equino-valgus is usually the result of primary paralysis of the tibialis anticus, the most powerful of the dorsal flexors; thus the foot is drawn somewhat outward in dorsal flexion, while the metatarsal bone of the great toe, having lost the support of the tibialis anticus muscles, falls downward and is drawn outward by the peroneus longus. In this type one's attention is often attracted by the peculiar appearance of the great toe which is deformed somewhat like a hammer toe by the over-action of the flexor longus pollicis in its attempt to take the place of the tibialis anticus. The equinus is usually slight and is secondary to the valgus. If the tibialis posticus is paralyzed in addition, the lateral displacement of the foot is more marked.

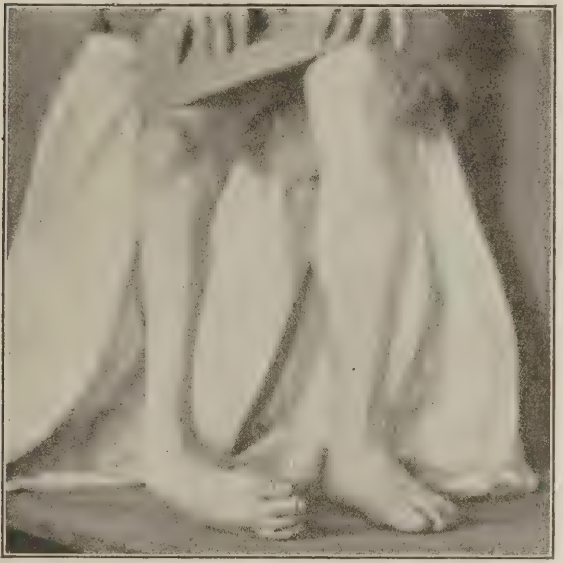

Fig. 2191.—Paralytic Deformity of the Foot, of the Varus Type. The atrophy and shortening of the limb are evident.

Treatment may be begun by placing the foot in a plaster bandage in an attitude of varus and allowing the patient to walk upon it until the tendency toward deformity has been overcome. A support with the catch, as for toe-drop, is applied to the shoe while the tendency toward valgus is checked by raising the inner border of the sole or by the use of a sole plate, as in the treatment of the simple weak foot.

Acquired simple talipes valgus, from paralysis of the tibialis anticus and posticus, is rare. Talipes valgus, as when the foot is dislocated outward, in cases of complete paralysis of all its muscles, may be regarded as a variety of dangle foot.

Talipes valgus, sometimes called spurious valgus, the simple weak or flat foot, has been described.

Traumatic valgus and equino-valgus, due to fracture at the ankle (Pott's fracture), may be treated by osteotomy of the tibia above the ankle in order that the proper relation of the leg to the foot may be restored. Equino-valgus of slight degree is not uncommon after tuberculous or rheumatic disease at the ankle or at the astragalo-scaphoid joints. This is practically one variety of the weak foot.

Talipes from Other Causes.—Talipes caused by cerebral disease or injury, whether of the paraplegic or hemiplegic type, is almost always in the form of equino-varus. The hemiplegic form of talipes is usually more unyielding and rigid than the paraplegic type.

The deformity must be corrected by the ordinary methods. In many instances, when the contractions are not marked, the after-treatment by a brace is not necessary.

Hysterical equino-varus or other forms of deformity are not especially uncommon. The diagnosis can be made by the other symptoms of hysteria, from the history of the onset and duration of the distortion, and from the appearance of the deformity which is evidently merely an assumed posture.

Tendon Transplantation for the Relief of Paralytic Talipes.—When one or more of the muscles are paralyzed the unbalanced action of those that remain tends to distort the foot. The object of tendon grafting or muscle transplantation is to utilize the power that remains by giving an active muscle a new point of attachment where it may be of service instead of an agent of deformity.

Tendon grafting is, as the name implies, the operation of attaching the tendon of a living to that of a paralyzed muscle. The first operation was performed by Nicoladoni in 1882 for the relief of paralytic calcaneus (*Archiv f. klin. Chir.*, 3, 27, S. 660, 1882). The tendons of the peroneus longus and brevis were divided behind the external malleolus, and the proximal ends united to the distal extremity of the divided tendo Achillis. The result was said to be satisfactory.

The first operation on the front of the foot was performed by Parish of New York (New York *Med. Jour.*, October 8th, 1892) for the relief of paralytic valgus, by attaching the tendon of the extensor proprius pollicis to that of the paralyzed tibialis anticus, without division of either tendon. In more recent years the field of the operation has been extended to include almost every possible combination of tendons and muscles.

Tendon grafting is most effective as a curative operation when but one muscle, for example an adductor or an abductor, is paralyzed. The most common form of this milder type is paralysis of the tibialis anticus, resulting in secondary equino-valgus. In Parish's operation the tendon of the adjoining extensor proprius pollicis was simply attached to that of the tibialis anticus, but as the extensor of the great toe is a very weak muscle, its power is hardly sufficient for the double task.

A more efficient procedure is to split the tendon of the paralyzed muscle. The outer half is then separated from its muscular attachment and the distal extremity is carried across the foot and is sutured to all the other tendons. The proprius pollicis is then attached to the inner half. In cases of longer standing and more marked deformity it is well to reduce the power of the abductors by cutting the tendon of the peroneus tertius from its insertion. This is then drawn beneath the other tendons and is attached to that of the tibialis anticus. All of the tendons may be sutured to one another, so that all may act as direct dorsal flexors.

If varus has resulted from paralysis of the peroneus tertius or brevis, or if there is weakness of the extensors of the toes, while the tendon of the tibialis anticus retains its power, it may be split, and the outer half, having been separated at the distal end, may be passed beneath the other tendons to be attached to the peroneus tertius, or a new attachment to the tissues on the outer border of the foot may be made.

Every variety of combination has been employed. The tendon of the peroneus longus has been brought across the foot and attached to the tibialis anticus for the relief of valgus, and a portion of the inner part of the tendo Achillis has been utilized for the same purpose, a procedure, however, that can hardly offer much prospect of success. Operations for the relief of calcaneus have been practically that of Nicoladoni, the transplantation of the two peronei muscles into the tendo Achillis; or, as modified by Goldthwait, the tendon of the peroneus longus was inserted into the tendo Achillis and the brevis was transplanted into that of the flexor longus pollicis. If the tibialis posticus is paralyzed with resulting valgus, the peroneus brevis may be carried beneath the tendo Achillis and attached to its distal extremity.

The operation of tendon transplantation should not be performed until the recovery from the paralysis is considered impossible. The incision should be sufficiently long to expose the tendon and the muscular substance. The paralyzed muscle is quite different in color from the normal, being dull reddish-yellow, and the tendon is usually dull white in place of the silvery glistening color of the normal tendon. The splitting of the tendon should be begun high up, including, in some instances, muscle substance, and in joining the splices as much surface as possible of each splice should be apposed because the tendons do not readily unite. In certain instances it may be advisable to attach the transplanted tendon directly to the periosteum at the point at which its force may be exerted to best advantage. This as a routine measure is advocated by Lange (*Münch. med. Wochen.*, November 15th, 1900).

Fine silk is usually employed for suturing. The tendon sheaths are, as far as possible, closed by fine catgut and the skin incision by the same material. Before the operation is performed, all resistance to normal motion should be overcome by force, and by division of the contracted parts, if necessary. The attachment of the muscles or tendons should be made while the foot is held in proper position, and in many instances it is well to cut and overlap the paralyzed tendons to aid in retaining the foot in the improved attitude.

After the operation is completed, the foot should be fixed in a plaster bandage in the over-corrected position for several weeks or months. As a rule the foot should be supported by a brace until it is evident that the union of the parts is firm, and a good functional result is assured.

The prognosis will depend entirely upon the character of the paralysis. If the tibialis anticus is alone affected, it may be hoped that sufficient power may be borrowed from the other muscles to lift the foot at least enough to prevent awkwardness of gait, and to restrain deformity. Even more favorable is the prospect for the relief of varus caused by weakness of the abductors; but it is impossible for weak muscles like the peronei to supply the place of the great calf muscle. The power obtained from the peronei, however, which has become useless and even harmful because it draws the foot into deformity, may be sufficient to hold the heel in proper position and at least to aid the brace in retaining the foot in a normal attitude.

The relative strength of the muscles should be considered in selecting grafts, as well as in making a prognosis. According to Fick it is as follows, in kilogrameters:

BACK OF THE LEG.

The calf muscle—gastrocnemius and soleus	8.21
Tibialis posticus	.40
Peroneus longus	.44
Flexor com. digitorum	.37
Flexor longus pollicis	.82
Total	10.24

FRONT OF THE LEG.

Tibialis anticus	1.61
Extensor proprius pollicis	.39
Extensor longus digitorum	.72
Peroneus brevis	.31
Peroneus tertius	.20
Total	3.23

The importance of the calf muscle on the back, and of the tibialis anticus on the front of the leg, is apparent. The former is nearly four times as strong as the other muscles of the combined posterior group, the latter being nearly equal to all the others on the front of the leg. (Rudolph Fick, "Ueber die Arbeitsleistung der auf die Fussgelenke wirkenden Muskeln," Leipsic, 1892.)

It has been claimed that the transplanted muscle may become hypertrophied sufficiently to carry out its new function, but this is somewhat doubtful. Direct transplantation of muscles on the same principle as tendon grafting has also been performed by Drobnik, Goldthwait, and others; for example, the sartorius, the gracilis, or the tensor vaginæ femoris may be transplanted into the substance of the quadriceps extensor muscle. Drobnik has suggested the possibility of regenerating the paralyzed muscle by thus engrafting a portion of one that is still active, but this is, of course, a possible rather than a probable outcome.

The principle of the operation applies, of course, to other parts of the body as well, but the opportunities for its application are far less frequent than in the lower extremities.

TENDON SPLICING.—Division and overlapping of the tendons of paralyzed muscles may be employed with advantage in certain instances. For example, in complete paralysis of all the dorsal flexors of the foot, each tendon may be shortened and attached to the anterior ligament; thus the toe-drop may be remedied or reduced to such an extent that the deformity may interfere but slightly with locomotion. In most instances, however, unless support is used the shortened part will relax subsequently.

ARTHRODESIS.—Arthrodesis, for the purpose of producing ankylosis of a joint, was first performed by Albert of Vienna, in 1878. Its field is practically limited to those cases in which no muscular power remains, the so-called dangle foot. It may be of service also in cases of partial paralysis, as in equinus or calcaneus, when the patient is unable to provide himself with apparatus.

The operation consists in opening the joint and removing the cartilage from the opposing surfaces of the bones, then sewing or nailing them to one another, or simply fixing the parts in a plaster bandage until union has taken place. If the case is one of simple calcaneus or equinus, without lateral deviation, the operation may be limited to the ankle joint, which may be opened from the back or front or side, as seems preferable. The cartilage is usually removed with a sharp spoon and at the same time relaxed tissue may be shortened after the Willett method, if the deformity be calcaneus; or the tendons on the front of the foot may be similarly shortened with the aim of lifting the toes to the proper level, if they are depressed. The operation, to be effective in cases of complete paralysis and dangle foot, must include all the larger joints of the foot. Even when ankylosis has been attained, there is a marked tendency to subsequent deformity. In cases of calcaneus, the removal of the astragalus in the manner described is the preferable operation.

Arthrodesis is also performed at the knee and at other joints for the purpose of fixing the part in a useful attitude. In certain instances the operation is indicated. It is, of course, limited to cases of hopeless paralysis and is more suitable to the older than to the younger class of patients.

The improvement in the gait obtained by the removal of deformity and fixation of the foot is often very marked, and support may often be discarded, but in early childhood, at least, cases should if possible be kept under observation in order that support may be applied if the deformity shows a tendency to recur.

Royal Whitman.

FOREARM, THE.—The forearm is that portion of the pectoral girdle or upper extremity lying between the elbow and wrist joints. Its bony framework comprises two bones, the radius and the ulna.

The *skin* of the forearm is soft and is usually well supplied with hairs, especially along the postero-external surface. Along the anterior surface the hairs are fewer and finer. The skin is freely movable throughout the forearm upon the deep fascial sheath. The bursa over the olecranon gives it free mobility at that point. Lying within the layers of the superficial fascia are the superficial veins and the cutaneous nerves.

The SUPERFICIAL VEINS rise in two plexuses: the large *plexus of the dorsum of the hand* which is derived from the digital veins, and the smaller *plexus of the front of the wrist,* from the palm and thumb. These veins are larger than those of the deep set, have fewer valves and return most of the blood. At points of communication between these sets of veins, valves are regularly found.

The veins arising from these two plexuses are irregular in their distribution and are seldom symmetrical upon the two sides in the same body. For convenience four principal vein trunks are distinguished upon the outer, anterior and inner surfaces of the forearm: the *radial,* the *median,* the *anterior* and the *posterior ulnar* veins respectively. The *median* vein as it reaches a point opposite the insertion of the biceps receives a communication from the deep set which perforates the deep fascia. This trunk is short and is known as the *profunda.* The median at once divides into branches that diverge in V-form, the median-cephalic to the outer side and the median-basilic to the inner side of the biceps. The *median-cephalic* ascends to a point a little above the elbow, is joined by the *radial* vein, and this trunk, called the *cephalic,* lies in the furrow to the outer side of the biceps in the arm. The median cephalic vein overlies the cutaneous branches of the musculo-cutaneous nerve as they pass the elbow. The *median-basilic* vein passes upward and inward and is usually joined at a point about in front of the internal condyle by both the *ulnar* veins. The trunk so formed is called the *basilic* and lies to the inner side of the biceps in the arm. The median basilic is usually larger and shorter than the median cephalic; the basilic is usually a considerably larger trunk than the cephalic. The median basilic vein overlies from without inward the bicipital fascial aponeurosis, the brachial artery, a part of the anterior division and the whole of the posterior division of the terminals of the internal cutaneous nerve.

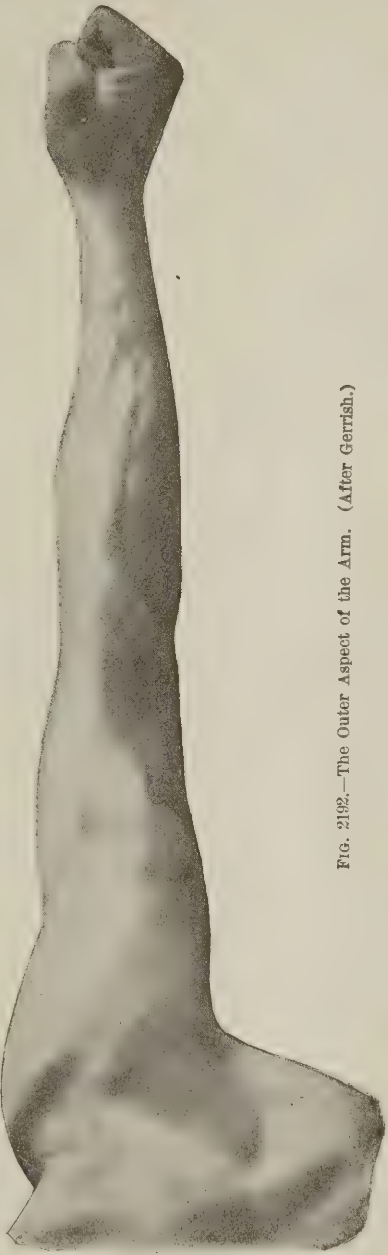

FIG. 2192.—The Outer Aspect of the Arm. (After Gerrish.)

SUPERFICIAL NERVES.—The cutaneous nerves are the musculo-cutaneous, with a few fibres from the musculo-spiral near the elbow, for supplying the outer side of the forearm, front and back; the internal cutaneous, for supplying the inner side of the forearm, front and back. Lying between the two on the back of the forearm is the distribution of the lower (larger) cutaneous branch of the musculo-spiral. All these nerves pass the elbow. Behind, over a small area, limited to the olecranon, is the nerve of Wrisberg.

Piercing the fascia at the lower third of the forearm, the following nerves become superficial or cutaneous: the palmar branches of the ulnar median and radial nerves on the front, and the dorsal branch of the ulnar nerve and the radial nerve on the back.

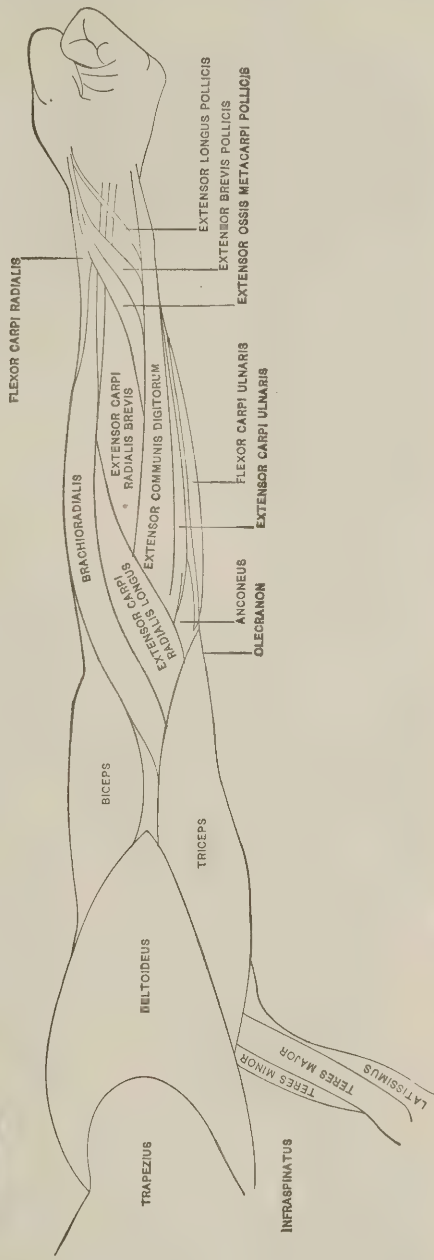

FIG. 2193.—The Outer Arm. Distribution of the Different Muscles. (After Gerrish.)

The *brachial* (deep) *fascia* at the elbow is firmly fixed to the bony prominences, and is strengthened in front by the bicipital fascia. This slip is given off from the tendon of insertion of the biceps, which bridges over the brachial artery, and is lost over the pronator teres and its sheath at the inner side of the forearm. Some fascial fibres are also often received from the tendon of the triceps. Together in the upper third of the forearm this deep fascia

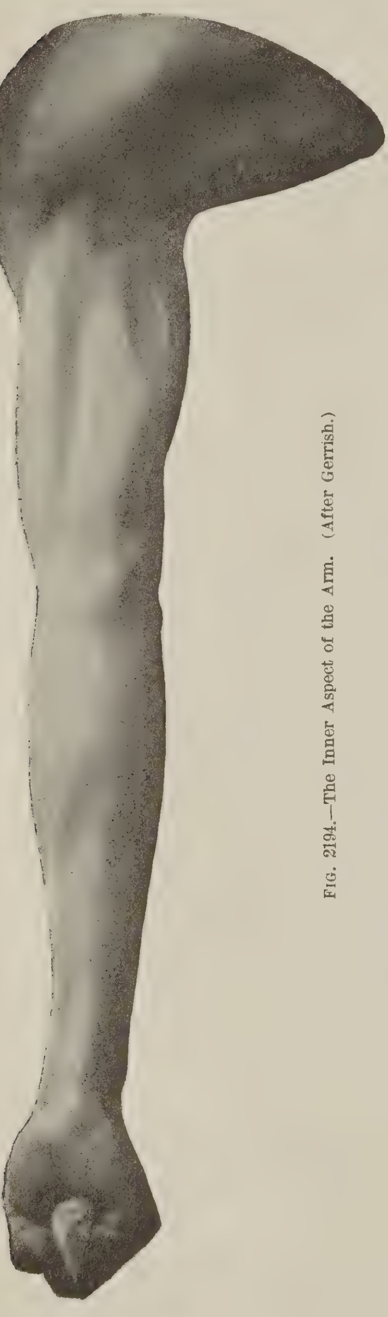

FIG. 2194.—The Inner Aspect of the Arm. (After Gerrish.)

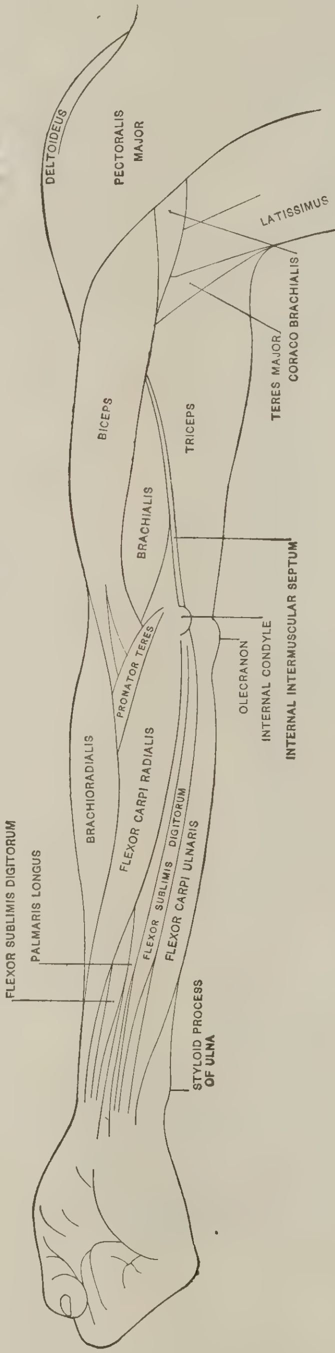

FIG. 2195.—The Inner Arm. Distribution of the Different Muscles. (After Gerrish.)

forms a strong enveloping sheath. Near the elbow at the internal condyle it serves in part as the origin of several muscles which spring from the condyle. Lower down in the forearm septa are given off from its deep surface to dip down between the various muscle bellies. In the lower third the fascia is continuous with the various muscle tendons and at the wrist forms the anterior and posterior annular ligaments. It ends in the fascia of the hand. It is attached to the posterior triangular area of the olecranon and to the whole of the posterior ridge of the ulna, and is much thicker behind. Between the superficial and deep layers of muscles, front and back, is a thin membranous layer of fascia. Below and behind the fascia is strengthened by transverse fibres to form the posterior annular ligament of the wrist which passes from the anterior border of the radius above the styloid process backward and inward, over the series of ridges forming grooves for tendons, over the ulna serving as an orbicular ligament, to attach itself to the inner aspect of the wrist, especially over the pisiform and cuneiform bones.

MUSCLES.—The muscles of the forearm, for convenience, can be divided into groups: those of the front, those of the back, and those of the outer side of the forearm. Those of the *front* (anterior radio-carpal) consist of a superficial set, five in number: the pronator teres, flexor carpi radialis, flexor carpi ulnaris, flexor digitorum sublimis, and (flexor) palmaris longus; and a deep set, three in number: flexor digitorum profundus, flexor pollicis longus, and pronator quadratus. The muscles of the *outer side* (radial), three in number, are: brachio-radialis, extensor carpi radialis longus, and extensor carpi radialis brevis. Those of the *back* (posterior radio-carpal) comprise a superficial set, four in number: extensor digitorum communis, extensor digiti minimi, extensor carpi ulnaris, and anconæus; and a deep set, five in number: supinator (brevis), extensor ossis metacarpi pollicis, extensor pollicis longus, extensor pollicis brevis, and extensor indicis.

The five muscles of the *superficial flexor* group are intimately associated at their origin from the internal condyle. Rising from it is a tendon common to them all, which gives fibres to each and sends septa between every two contiguous muscles. The muscles, from without inward, are the following:

The *pronator teres*, the most external, crosses obliquely the upper half of the forearm. It rises by two heads: one, large and superficial, from the inner condyle of the humerus, by a tendon common to both heads, and from the supracondylar ridge, fascia, and intermuscular septa; the other, a thin and deep band, coming from the inner side of the coronoid process and soon joining the deep surface of the large head. This slip separates the median nerve from the ulnar artery. The muscle thus formed passes outward and ends in a flattened tendon which turns over the radius and is inserted into a rough impression on the outer surface of the shaft of the radius about at its middle. Near the insertion the muscle is crossed by the radial artery and is covered by the brachio-radialis.

The *flexor carpi radialis* rises from the flexor tendon, from fascia, intermuscular septa, and adjacent muscles. At about the middle of the forearm its fleshy belly merges into a long flattened tendon, passes in a special compartment of the anterior annular ligament, grooves the trapezium, and inserts itself into the base of the second and frequently into the third metacarpal bone.

The (*flexor*) *palmaris longus* is a long slender muscle, the smallest of the group. It rises from the flexor tendon, fascia, and septa, to form soon a small round belly. It soon ends in a long slender tendon which inserts itself into the lower border of the annular ligament and the palmar fascia. This muscle is very variable and is often absent.

The *flexor carpi ulnaris*, the innermost muscle of the group, rises by two heads: the one from the back part of the flexor tendon, the other from the inner side of the olecranon and, by an aponeurosis, from the upper two-thirds of the posterior border of the ulna. The two heads bridge the space between the internal condyle and the olecranon, and between and beneath them the ulnar nerve is transmitted. The muscle converges into a tendon which is placed along its front surface and inserts itself into the pisiform bone.

The *flexor digitorum sublimis* (flexor perforatus) is a broad flat muscle placed behind the preceding. It rises by a strong head from the flexor tendon, from the internal lateral ligament of the elbow joint, from the inner border of the coronoid process, and from the overlying muscles and septa; and by a second head, a thin flat band, from the anterior oblique line of the radius and its anterior border. It merges from a broad muscle into four separate tendons which first pass through the middle compartment of the anterior annular ligament, then diverge, and continue their course, each one separately, in company with a corresponding tendon from the profundus (behind), to each of the last four fingers. At the wrist the tendons pass in pairs, those for the third and fourth fingers being in front, those for the second and fifth lying behind the first pair. The tendons opposite the first phalanx divide, allow the profundus tendon to pass between, then unite behind to insert themselves into the second phalanx.

The *deep-seated flexor* group comprises the following muscles:

The *flexor digitorum profundus* (flexor perforans), a large thick muscle, rises from the upper three-fourths of the front and inner side of the ulna, from the ulnar half of the interosseous membrane, and from the aponeurosis of the flexor carpi ulnaris. It divides finally into four tendons for the inner four fingers, but the tendon for the index finger becomes distinct in the forearm. It passes behind the sublimis at the wrist, behind the sublimis tendons in the palm, and after perforating the sublimis inserts itself at the bases of the last phalanges of the inner four fingers. The lumbricales take origin from the tendons in the palm.

The *flexor pollicis longus*, to the outer side of the profundus, rises from the front of the radius between the oblique line and the pronator quadratus, and the adjacent interosseous membrane. From a fleshy belly, a round tendon passes under the annular ligament and thenar eminence to its insertion at the base of the second (last) phalanx of the thumb. Occasionally a second head rises from the coronoid process or internal condyle in common with the sublimis.

The *pronator quadratus* rises from the pronator ridge and from the front of the ulna at its lower fourth, passes close to the bones, and inserts itself into the front of the lower end of the radius.

The muscles of the *outer* (radial) *extensor* group are:

The *brachio-radialis* (supinator longus) rises from the upper two-thirds of the external supracondylar ridge and from the front of the external intermuscular septum. It forms a long slender muscle which, near the middle of the forearm, merges into a flat tendon; and this, in turn, inserts itself into the outer side of the radius near the base of the styloid process.

The *extensor carpi radialis longus* rises just below the preceding muscle fom the ridge and septum, a few fibres being derived from the common extensor tendon. From this origin a long tendon passes under the posterior annular ligament in its second compartment and passes to its insertion into the base of the second metacarpal. In its course it lies upon the following muscle.

The *extensor carpi radialis brevis* rises by the common extensor tendon from the external condyle of the humerus, from the intermuscular septa, and from the external lateral ligament of the elbow. Its tendon passes with the longus in the same compartment at the wrist and is finally inserted into the base of the third metacarpal.

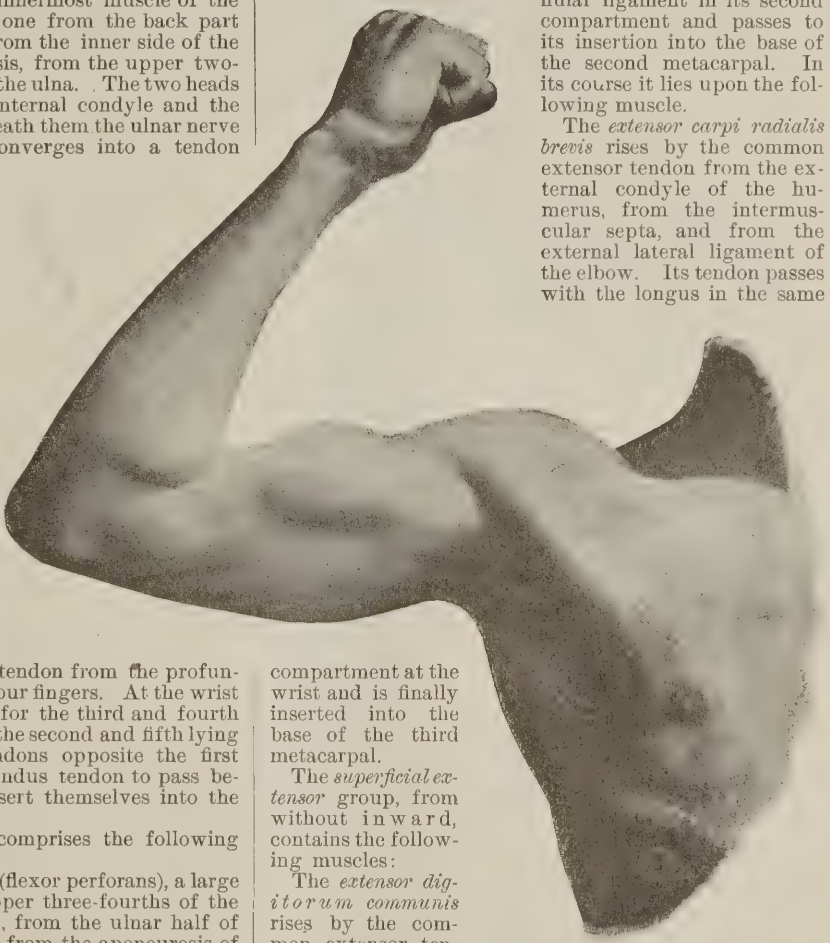

Fig. 2196.—The Inner Arm. Muscles contracted. (After Gerrish.)

The *superficial extensor* group, from without inward, contains the following muscles:

The *extensor digitorum communis* rises by the common extensor tendon, fascia, and septa. From a fleshy belly four tendons are ultimately given off, and these pass through the fourth compartment of the posterior annular ligament on their way to the hand. Here they diverge and then pass on to the points where they are inserted at the bases of the second and the third phalanges of the inner four fingers.

The *extensor digiti minimi* lies at the inner side of the preceding muscle. It rises in the same manner as does the latter and passes through the fifth compartment at the wrist (between radius and ulna); its points of insertion are the same as those of the corresponding tendon of the preceding muscle.

The *extensor carpi ulnaris* rises in the same manner as the preceding, and also by an ulnar aponeurosis common to it, the flexor carpi ulnaris, and the flexor profundus. The tendon emerges near the wrist, passes in the sixth compartment, and is inserted into the base of the fifth metacarpal near its ulnar border.

The *anconæus* rises from the lower part of the back of the external condyle and from the adjacent posterior ligament of the elbow and is inserted into the outer surface of the olecranon and the upper third of the back of the ulna. This muscle is sometimes continuous with the triceps and is usually described in connection with it, as a fourth head.

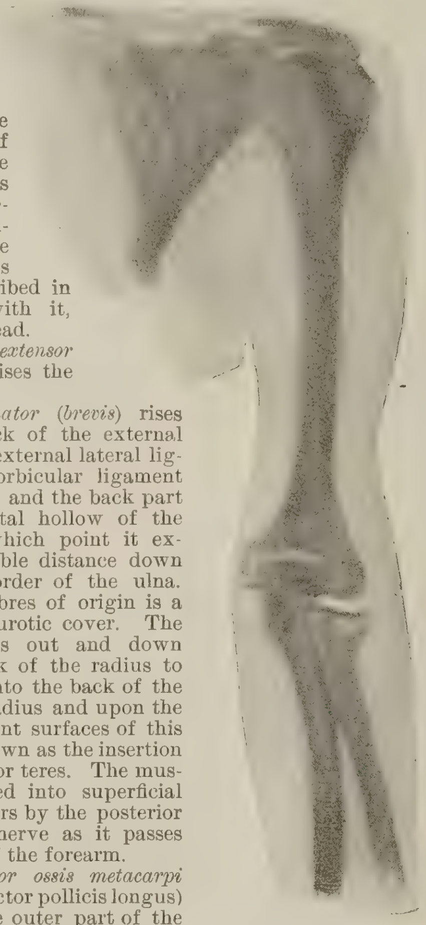

FIG. 2197.—Skiagraph Showing Relations of Bony Framework of the Shoulder, Arm, and Elbow to the Soft Parts which Surround Them. (After Gerrish.)

The *deep extensor* group comprises the following:

The *supinator* (*brevis*) rises from the back of the external condyle, the external lateral ligament, the orbicular ligament of the radius, and the back part of the bicipital hollow of the ulna, from which point it extends a variable distance down the outer border of the ulna. Over these fibres of origin is a strong aponeurotic cover. The muscle passes out and down over the back of the radius to insert itself into the back of the neck of the radius and upon the outer and front surfaces of this bone as far down as the insertion of the pronator teres. The muscle is divided into superficial and deep layers by the posterior interosseous nerve as it passes to the back of the forearm.

The *extensor ossis metacarpi pollicis* (abductor pollicis longus) rises from the outer part of the back surface of the ulna at the junction of the upper and middle thirds, from the corresponding portion of the interosseous membrane, from a small part of the back of the radius near its middle, and from intermuscular septa. The muscle extends down and out, emerges between the extensor digitorum communis and the extensor carpi radialis brevis, and in company with the extensor pollicis brevis it crosses the two radial extensors. At about this point it merges into its tendon, follows down the outer side of the base of the radius, and enters the first compartment of the posterior annular ligament. It is inserted into the outer side of the base of the first metacarpal bone and by its aponeurosis into neighboring structures, notably the back of the trapezium, and also into the palmar fascia, especially that part which covers the thumb.

The *extensor pollicis brevis* (extensor primi internodii pollicis) rises from the middle of the back of the interosseous membrane just below the preceding, from the back of the radius extending obliquely outward and downward, and from the intermuscular septa of this group of muscles. It extends obliquely down and out and forms its tendon at the lower third of the forearm. From this point it accompanies the tendon of the preceding muscle, lying behind it, to be inserted into the base of the first phalanx of the thumb.

The *extensor pollicis longus* (extensor secundi internodii pollicis) rises from the outer part of the back of the ulna at its middle third, close to the outer border, from the interosseous membrane, and from the septum between it and the extensor indicis. This muscle, somewhat stronger than the preceding, passes down and out to merge into a tendon placed along its back. The tendon becomes free just above the posterior annular ligament, passes through its third compartment, then over the radial extensors, lies close to the inner side of the tendon of the preceding, and is inserted into the base of the second phalanx of the thumb.

The *extensor indicis* rises from the back of the ulna (from a point just below the preceding muscle to one situated nearly at the lower end of the bone), from the adjacent interosseous membrane, and from the septum between it and the preceding. It merges into a tendon which is placed along its radial border. This becomes free at the lower third of the forearm, passes through the fourth compartment beneath the tendons of the extensor digitorum communis, and after it emerges from this it is inserted into the inner border of the tendon of the common extensor of the index finger at about the metacarpophalangeal joint.

ARTERIES.—The *brachial artery* ends just below the bend of the elbow where it divides opposite the neck of the radius into its two terminals, the radial and the ulnar.

The *radial artery*, the smaller of the two, extends downward, in direct continuation of the brachial artery, along the outer side of the front of the forearm to the lower end of the radius. Here it turns around the outer side of the radius to the back of the wrist, over the external lateral ligament, and under the extensors of the thumb.

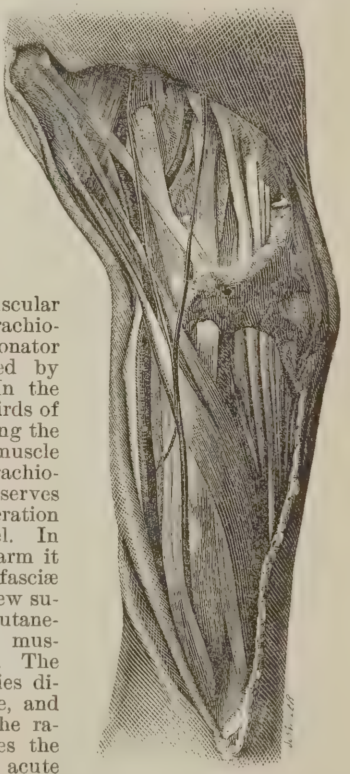

FIG. 2198.—External and Posterior Region of Wrist, showing Arrangement of Tendons, Artery, Nerve, etc. The skin and fasciæ have been removed. (Reduced in size.) (After M. H. Richardson.)

In the upper forearm it lies in the outermost intermuscular space between the brachioradialis and the pronator teres, and is covered by fasciæ and skin. In the middle and lower thirds of the forearm it lies along the inner border of the muscle and tendon of the brachioradialis, which latter serves as a guide in the operation for ligating this vessel. In this part of the forearm it is covered only by fasciæ and skin, and by a few superficial veins and cutaneous branches of the musculo-cutaneous nerve. The radial at the wrist lies directly upon the bone, and forms the pulse. The radial nerve approaches the artery above at an acute angle; in the middle and lower thirds it lies along its outer side. The venæ comites accompany the artery on either side.

The radial artery in the forearm, besides the irregular and numerous muscular branches, gives off the radial recurrent, the anterior radio-carpal, and the superficial volar.

The *radial recurrent*, a branch of considerable size, is usually given off from the outer side of the radial just below its origin from the brachial. It runs outward between the brachio-radialis and the supinator (brevis), divides into several branches and anastomoses with the interosseous recurrent and superior profunda, and gives off a branch to supply the elbow joint.

The superficial volar and the anterior radio-carpal are branches given off just above the wrist.

The *ulnar artery*, the larger of the terminals of the brachial, from the inner side of the neck of the radius passes down and inward to the front of the inner (ulnar) side of the forearm, thence directly to the wrist, and over the anterior annular ligament to the palm.

In the upper half of its course the artery lies deeply beneath the pronator teres and the superficial flexors; in the lower half of the forearm it is overlapped only by the flexor carpi ulnaris muscle and tendon which lie to its inner side and serve as a guide in operations for ligating the vessel. Only in the last inch or so is the artery superficial. As the artery lies beneath the pronator teres it is crossed from within outward by the median nerve, the deep head of the muscle usually separating the two. The ulnar nerve approaches the artery from behind the inner condyle at an acute angle, being separated from it by the flexor sublimis, and in the lower two-thirds it lies close to the inner side of the artery. The latter is covered by superficial ulnar veins, in addition to fasciæ and skin, and is crossed by branches of the internal cutaneous nerve. The artery is accompanied by two venæ comites.

The ulnar artery, besides numerous and irregular muscular branches, gives off the anterior and posterior recurrent ulnar, the anterior and posterior interosseous, the anterior and posterior ulnar carpal, and usually the nutrient of the ulna.

The *anterior recurrent ulnar*, the smaller of the two recurrent branches, runs up in front of the inner condyle of the humerus, between the pronator teres and the brachialis, and anastomoses with the anterior branch of the anastomotica magna and a branch of the inferior profunda.

The *posterior recurrent ulnar*, the larger, passes inward between the flexor sublimis and the flexor profundus, then up and back of the inner condyle of the humerus, and comes to lie, with the ulnar nerve, between the two heads of the flexor carpi ulnaris. It anastomoses with the posterior branch of the anastomotica magna, with the inferior profunda, and with the interosseous recurrent to form the olecranal rete.

The *interossei* rise from the ulnar by a common trunk about half an inch in length, and the latter, in turn, rises from the outer and back part of the ulnar just before the median nerve crosses the main vessel. It rises about an inch below the origin of the ulnar, and proceeds backward to the interosseous membrane, where it divides into its two terminals.

The *anterior interosseous*, the smaller, follows the front of the membrane in company with two veins and the deep branch of the median nerve which lies to its outer side. It usually supplies nutrients to both bones.

The *posterior interosseous*, the larger, passes back between the interosseous membrane and the oblique ligament above, descends between the superficial and deep muscles, and, crossing the extensors of the thumb and index finger, anastomoses below the latter muscle with the anterior interosseous.

The anterior and posterior ulnar carpals are small carpals which, in company with the anterior radial carpal, anastomose and form the carpal arch.

NERVE TRUNKS.—The nerve trunks of the forearm are the radial, posterior interosseous, median, and ulnar.

The *musculo-spiral* nerve, a short distance above the elbow, lying upon the brachialis and covered by the brachio-radialis, divides into its terminals, the posterior interosseous and the radial nerves.

The *posterior interosseous* nerve passes back, out, and down between the brachialis and extensor carpi radialis longus, through the supinator (brevis), to the deep layer of the forearm extensors. It approaches the posterior interosseous artery at an angle, and is in relation with it as far as to a point below the origin of the extensor pollicis longus where it approaches and is in relation with the posterior branch of the anterior interosseous artery. Lower down, it passes through the fourth compartment of the wrist, with the extensors communis and indicis, to the back of the wrist where it becomes ganglionic.

The *radial* nerve passes directly downward under cover of the brachio-radialis. At the middle third of the arm it lies along the outer side of the radial artery, then winds around the outer side of the radius under cover of the brachio-radialis tendon, and pierces the deep fascia in the lower forearm, breaking up into its terminal branches on the back of the wrist.

The *median* nerve, from the bend of the elbow, where it lies to the inner side of the tendon of the biceps, the brachial, and the beginning of the ulnar artery, passes down the centre of the front of the forearm beneath the condylar head of the pronator teres and over the ulnar artery, being separated from the latter by the deep head of the same muscle. Beyond this point it passes beneath the radial head of the flexor digitorum sublimis, and later still it lies deep beneath the flexor sublimis and on the flexor profundus. At the wrist the nerve becomes superficial and lies between the tendons of the flexor sublimis to the inner side, and of the flexor carpi radialis on the outer side. It passes superficially through the large flexor compartment of the anterior annular ligament and soon divides into an inner and an outer terminal. Besides muscular branches in the forearm, the median gives off the anterior interosseous and small branches to the elbow joint.

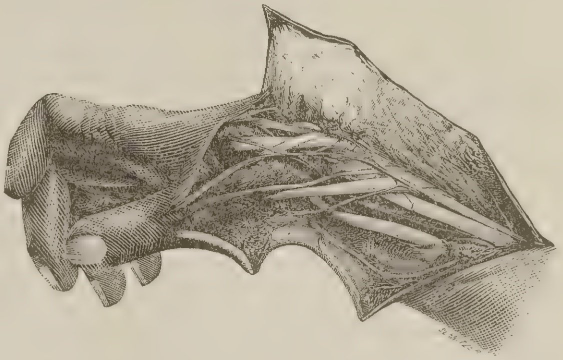

FIG. 2199.—Dissection of the External Region of the Right Wrist. The radial artery is seen between the relaxed tendon of the flexor carpi radialis below, and the brachio-radialis on the outer (upper) side. It then passes beneath the first two extensors of the thumb and a small branch of the radial nerve, crosses the base of the thumb obliquely, and disappears under the tendon of the extensor pollicis longus. (Thin subject, female, one-half normal size.) (After M. H. Richardson.)

The *anterior interosseous* nerve is given off from the median opposite the insertion of the biceps, runs down the front of the membrane in company with the anterior interosseous artery, and supplies the medullary arteries, the periosteum of the radius and ulna, and the wrist joint.

The *ulnar* nerve, from the angle between the olecranon and the internal condyle, passes between the inner and outer heads of the flexor carpi ulnaris to the front of the forearm. It passes down upon the flexor profundus under cover of the flexor carpi ulnaris and overlapped by it upon the inner side. It passes nearly to the wrist along the outer side of this muscle and its tendon, when it becomes superficial and enters the hand anteriorly to the annular ligament. In the lower two-thirds of the forearm the ulnar artery lies to its outer side, separating it from the flexor sublimis. It also, besides giving off muscular branches, supplies the elbow joint.

The *interosseous membrane* bridges across between the interosseous borders of the radius and ulna, from a point a little below the bicipital tubercle of the radius to the wrist joint. Its fibres pass mainly in an oblique direction from the radius to the ulna. The posterior interosseous vessels pass back over its upper border and are in relation with its back surface low down in the forearm. The anterior interosseous vessels and nerve are in relation with the front surface throughout. Except in supination of the forearm and in full pronation this membrane is usually tense. It serves also to carry strains from the radius to the ulna and to bind the bones together.

The forearm is subconical, so that the lateral flap operation is a necessity, since the skin cannot be pushed far upward in the lower forearm. The skin is, also, quite adherent to the underlying aponeurosis. Roughly speaking, the intermuscular septa, the bones, and the interosseous membrane form a front and a back compartment. The *ulna* is subcutaneous from olecranon to styloid process, so that any injury or fracture is readily manifest. The *radius* lies deeply lodged among the upper forearm muscles and it is only occasionally that its head can be felt. In the lower forearm the radius becomes gradually subcutaneous and can be examined. The *interosseous membrane* is relaxed in the semi-prone position of the forearm, which indicates the best position, in fracture of the radius or ulna, for splinting. Care should be exercised not to permit the fractured ends of the radius to rest upon the ulna, thereby causing injury to interosseous vessels and nerves and favoring an eventual ankylosis. Antero-posterior splints may press too much upon radial and ulnar vessels and nerves and injure them.

The *muscles* of the forearm, in extremely muscular subjects after too long and severe use, may cause pressure upon arteries and nerves, and resultant pains and neuralgias. Muscular spasm may effect the same results. Muscles become greatly hypertrophied under special exercises (as occurs, for example, in the pronator teres muscle of the "tennis arm"). A spasm of the same muscle may take place, as in the "glass arm" of baseball pitchers. Hypertrophy of both of the pronators, the result of "feathering," may take place in the case of oarsmen. The inner edge of the brachio-radialis is the guide to the *radial artery* and nerve; the inner edge of the palmaris tendon is that for the *median nerve;* and the outer border of the flexor carpi ulnaris indicates where the *ulnar artery* and nerve are to be sought for. Both arteries may be ligated at any point above the annular ligament for severe hemorrhage of the palm. Above the anterior annular ligament the two synovial tendon sheaths of the flexor pollicis longus and that common to the sublimis and profundus extend for a distance of an inch and a half, and often carry infection from the palm to the tendon spaces of the forearm.

Through the posterior annular ligament extend upward six such sheaths, all of which save the last extend well above the ligament. They are: one for the two outer thumb extensors, one for the two radio-carpal extensors, one for the long thumb extensor, one for the common extensor, one for the little finger extensor, and lastly one for the ulno-carpal extensor.

Injuries of the *nerve* trunks may cause varying symptoms. (Compare *Arm.*) The *posterior interosseous nerve* may be injured in resection of the head of the radius or in fracture of the radial neck, and thus may cause paralysis of the extensors. The posterior interosseous nerve may suffer loss of function from fracture of the humerus at some point near its middle. Pressure upon the *median nerve* in muscular spasm and in compression from long and severe muscular exercise, may cause increased cramps and pain or even a prolonged neuralgia. The *ulnar nerve* may be injured in fracture of the olecranon and may cause loss of sensation, or numbing; or it may be caught in the callus of fracture, either there or along the shaft of the ulna, and cause pain; and, finally, the conditions may be such as to necessitate excision of the nerve from the callus. The numbness from a sudden blow upon the ulnar nerve at the elbow —commonly spoken of as "striking the funny bone"— is a familiar instance; and if severe, this numbing and tingling may be persistent and may be accompanied by loss of function of the flexor muscles. In plumbism the ulnar nerve is regularly involved, causing the "claw hand." The ulnar and median nerves are both involved in alcoholic neuritis. The *radial nerve* may be painful at its points of distribution if the trunk is injured in Colles' fracture. Neuromata along the nerve trunks, due to injury, may demand excision.

Luzerne Coville.

References: Joessel, Quain, Morris, Gerrish, Keen, Holden, Cunningham, Gray.

FORMALDEHYDE, formic aldehyde, methyl aldehyde or oxymethylene (HCOH), is a gas whose saturated aqueous solution is known as *formalin* or *formol.* The method of manufacture used now on a large scale is a modification of that used by A. W. Hoffmann, who introduced formaldehyde in 1867. By means of superheated steam passing through a copper coil, methyl alcohol is vaporized under pressure in a steel chamber, from which it issues with great force and mixed with a definite quantity of air, and then passes through a double tube converter. The inner tube of this is perforated with very fine holes and separated from the outer tube by broken coke, and the whole is kept at a dull red heat. As it passes through this heated coke, the vapor is oxidized to formaldehyde, and this is either condensed by extreme cold to a liquid, or cooled and dissolved in water by agitation. Copper filings, spongy platinum, or any porous material may be substituted for coke. The gas is usually generated on a small scale by heating paraformaldehyde, though methyl alcohol can be employed by heating in a tin vessel so that the vapor will pass through a perforated red-hot copper plate. The reaction is: $CH_3OH + O = CHOH + H_2O$. The yield is said to be only twenty per cent. from commercial wood alcohol. Other methods of manufacture are by the complete oxidation of ethyl nitrate; by heating a mixture of ethylene and oxygen to 400° C.; by the dry distillation of calcium formate, etc.

Formaldehyde is a colorless gas of pungent, penetrating odor, and very irritating to the eyes and nose. Its saturated cold aqueous solution (formalin) contains from thirty-five to forty per cent. of the gas by weight, is colorless, has a sharp taste, and mixes freely with water, alcohol, and glycerin. The gas is more soluble in methyl alcohol than in water. Its chemical affinities are extensive. It is rendered inert by alkalies, deodorizes hydrogen sulphide, and is the basis of many aniline colors and new synthetic remedies, such as urotropin, bismal, tannoform, etc. It reduces Fehling's solution, produces a black precipitate with ammoniacal silver-nitrate solution, and white precipitates with dilute aqueous solution of aniline and with ammonia and bromine water. Henner's test, sensitive 1 in 200,000, consists in superposing a mixture of very weak carbolic acid with the suspected liquid upon concentrated sulphuric acid; a rose-violet ring at the line of contact indicates formaldehyde. A modification of this is to dissolve 0.1 gm. morphine hydrochlorate in 1 c.c. of sulphuric acid and add to this the suspected liquid. In milk and such fluids, however, these tests may be obscured by the charring of the organic substances by the acid; hence, in such a case, the formaldehyde should be distilled off and passed into water, and then tested for. Jorrissen's test was designed for milk: shake together 25 c.c. of milk and 10 c.c. of 0.1 per cent aqueous phloroglucin, add 5 to 10 c.c. of one-third strength potash lye, and a transient salmon-red color indicates formaldehyde.

When formalin is heated, part of it is converted into paraformaldehyde (paraform, triformol, or trioxymethylene), which separates as a white insoluble flocculent mass, capable of again yielding HCOH gas. Formaldehyde renders gelatin insoluble, forming elastic translucent masses, so it has been used to replace tannin in making leather and to harden gelatin films in photography. Formaldehyd-gelatin is employed as an absorbable antiseptic. When added to serum albumin, formalin prevents coagulation by heat; added to calcium carbide, it retards the evolution of acetylene gas. It neutralizes alkalies by forming with them complex substances, that with ammonia being hexamethylene-tetramine.

It is said not in any way to affect the textile character of wool, cotton, fur, silk, or leather; and it does not change their colors except in the case of iron-containing dyes or a few of the aniline colors such as fuchsin (aniline red). Its aqueous solution attacks metals; consequently the dry gas only should be used for sterilizing instruments. In 1886 its powerful bactericidal properties were reported by Loew, and it has now become an almost universal disinfectant (see *Disinfectants* and *Disinfection*). Rubber goods, catheters, etc., may be kept sterile in a weak solution for a long time without harm. Hoffmeister, Hirst, and others have used it for sterilizing catgut.

It is also used largely as a hardening and fixing agent, and as a preservative for anatomical and biological specimens. These, especially plants, tend to retain some of their brilliant colors, and do not shrink as they would in alcohol. Plants slowly discolor the solution by giving up their tannin. As formaldehyde has little penetrating power, openings should be made so that it may permeate the interiors of specimens; otherwise they may rot, even in strong solution. Moulds have been found growing on tissues apparently saturated with solutions of five to ten per cent. strength. Orth's hardening and fixing formula is: Müller's fluid, 100 parts; formalin, 10 parts. To be mixed just before use. Kaiserling keeps the specimen for twenty-four hours in formalin 75, potassium nitrate 1, potassium acetate 3, distilled water 100, then transfers to 80-per-cent. alcohol for twelve hours, then to 95-per-cent. alcohol for two hours. The specimen may then be mounted for sectioning, or kept in equal parts of water and glycerin containing 3 per cent. of potassium acetate. Before putting through alcohol, Carter leaves the tissues for from six to twelve hours in 20-per-cent. formaldehyde solution with 5 per cent. acetic acid. Blood smears exposed to the vapor are firmly fixed, and may be stained as by any other method of fixing. Blood on the hands becomes hardened and difficult to wash off.

Being difficult of detection in small quantities, it is used as a preservative of foods and medicines, vigorous prohibitive laws not preventing its widespread use by dairymen, canners, etc. In the strength of 1 to 20,000 it is said to preserve milk for several days, yet even this minute quantity has been shown by Annett and others to be harmful. It has been employed by pharmacists for the preservation of ointments, syrups, fruit juices, infusions, and various other articles which readily spoil. Mucilage of acacia, lard, cider, etc., remained sweet after a year, yet the odor of formaldehyde could not be detected at any time. Once added to an article, a portion of it remains persistently and cannot be driven off by heat. The best means of neutralizing it in vapor or in solution is by ammonia.

Physiological Action and Toxicology.—Formaldehyde vapor is a powerful irritant to the eyes and the mucous membranes of the respiratory tract. Applied in solution to the skin it smarts, but usually for a short time only. Severe urticaria is reported to have followed its application. The solution in glycerin is said to be less irritant. Taken by mouth it retards digestion even in small dosage, especially the pancreatic digestion of albumin. In strong solution it may cause vomiting. It weakens pulse and respiration and is depressing to the vital functions. The ingestion of several ounces of formalin by an adult was followed by unconsciousness, marked pallor, cold clammy perspiration, increased respiration, and râles over both lungs. The urine contained formic acid. In a few hours anuria developed, and the next morning the coma disappeared, and the patient acted as if drunk, complaining of headache, conjunctivitis, and a sore mouth. He recovered in twenty-four hours (Klueber). In England, the drinking of two ounces of a four-per-cent. solution resulted in death from heart failure twenty-nine hours later. The autopsy showed corrosive action on the œsophagus and stomach. Fischer (1901) reported to the Chicago Pathological Society an experimental study of the action of formaldehyde on animals. Inhalation resulted in marked inflammation throughout the respiratory tract. Dosage by stomach produced vomiting, subnormal temperature, rapid weak pulse, and death. Sometimes the death was sudden. Necropsy revealed intense gastritis, with congestion, necrosis, and leucocyte infiltration. Intraperitoneal injections were followed by a fibrino-hemorrhagic peritonitis of an intensity referable to the strength of the solution. Small repeated intraperitoneal injections of dilute solutions stimulated great connective-tissue proliferation. Eye instillations caused iritis. Every case showed early eosinophilia followed by general leucocytosis, and degenerative changes with focal necroses in liver and kidneys. Experiments in France show that fleas easily succumb to the vapor, but that to kill rats and mice requires as much as 8 or 10 gm. to the cubic metre of air space.

The best local antidote is ammonia, though other alkalies are of some avail. Ammonia gas quickly neutralizes the irritating vapors in a room. For the stomach it may be given as the aromatic spirit of ammonia or the liquor ammonii acetatis. When formalin is swallowed, vomiting should be promoted, or the stomach emptied by lavage. Stimulants, especially aromatic spirit of ammonia and caffeine, and hypodermics of strychnine should be administered, external heat applied, and absolute recumbency enjoined. Demulcent drinks may be given to allay irritation.

Therapeutics.—As a general disinfectant and deodorizer this drug is undoubtedly without a peer, though its penetrating power is not great (see *Disinfection*). In the respiratory passages it is of pronounced value as a prophylactic and curative in *influenza* and *pertussis*, and in allaying the cough and sweetening the sputum in *tuberculosis*. It is also used in *chronic pharyngitis*, in *atrophic rhinitis* (principally as a deodorizer), and as a *mouth wash*. It is said to be of less use in *diphtheria*, as it does not penetrate the dense membrane. A few drops of ℞ Aq. chloroformi ʒ iij. (12 c.c.), ether ℥ ss. (15 c.c.), formaldehyde solution (6 per cent.) ad ℥ iv. (120 c.c.) may be sprinkled on the sponge of a zinc respirator, and inhaled for fifteen minutes. Or one can use as a mouth wash or spray a mixture of 40-per-cent. formaldehyde solution ʒ i. (4 c.c.), glycerin ʒ iv. (15 c.c.), and water to make ℥ iv.–vi. (120 to 180 c.c.). The method of treating *tuberculosis* by cataphoresis or the electrical transmission of formaldehyde directly into the human body, the writer saw tested scientifically with negative results.

For *suppurative otitis media* Reik recommends irrigation twice a day with ʒ i. (4 c.c.) of formalin in O i. (500 c.c.) of water. Ward uses five to ten drops of a one-per-cent. solution, and in *acute otitis* three drops at a time.

In the mycotic skin diseases, such as *sycosis*, *ringworm*, and *favus*, the strong solution may be applied every other day. Cures resulted from one to four applications (Salter, Daniel). For *seborrhœa* Ravogli advises rubbing with ℞ Formalin, ʒ i.–ij. (4–8 c.c); glycerin, ʒ ij. (8 c.c.); aq. coloniensis, alcohol, āā ℥ iij. (90 c.c.).

Hyperidrosis pedis may be checked for a week or two (Hahn, Hirschfeld) by momentarily immersing the feet in pure formalin, or by applying it with a brush. Unna applies adeps lanæ 20, vaseline 10, formalin 10–20. The application of formalin to eczema or intertrigo Unna found to be very painful. He then tried a gelatin mask hardened with formalin for lupus, erythema centrifugum, lepra, and obstinate chronic eczema, but was obliged to discard it. Next he employed formalin as a corrosive for carcinoma, lupus, condylomata, and ulcers. The diseased tissues were cleanly destroyed, the necrotic surface being dry and odorless, but the development of a line of demarcation took so long a time that other means were deemed preferable. He found formalin of value, however, in *inoperable carcinoma*, as it deodorizes and mummifies the part. For *condylomata* and other soft skin protuberances he uses paraform collodion, which possesses the advantage of keeping the growths dry. Daniel rubs formalin into *warts* with a stick, and these shrink and come off without leaving a scar.

As a vaginal douche Crawford recommends formalin in *obstetrics*, and Van Winckel uses ʒ i. (4 c.c.) to a quart (1 litre) for *endometritis* or for *vaginitis*, especially gonorrhœal. It may be used in full strength in the treatment of *chancroids*.

Surgically it is an antiseptic of great power (see *Disinfectants* and *Disinfection*), and is used for sterilizing the hands, dressings, sutures, and instruments. Hoffmeister, Hirst, and others recommend it highly for catgut. Hoffmeister's method is to harden the catgut on glass spools in four per cent. formaldehyde for twenty-four hours, then boil in water for ten minutes and keep in alcohol containing five per cent. of glycerin and 0.1 per cent. of corrosive sublimate. Vandermarker states that it should not be used directly in wounds, as one-per-cent. solutions will destroy fresh granulations, and two-per-cent. will produce sloughs. Its combination with gelatin (glutol), however, is used thus by Schleich and others. Inoperable epitheliomata and sarcomata have been treated with injections of one-half-per-cent. solution (about twenty minims) followed by curetting of the hardened tissue. The bleeding has been slight, and the growths have practically disappeared after a few treatments (Mitchell, Thompson). Ravogli claims to obtain the same results from the application of a paste of rice powder, oxide of zinc, and formalin. In chronic tuberculous joints, tuberculous abscesses, and empyema, Hahn considers a one-per-cent. glycerin solution to be more efficient than the much used iodoform-glycerin.

In dentistry, paraformaldehyde is preferred, as, being in solid form, it can be placed in cavities, disinfecting them by slowly evolving formaldehyde gas.

The more common preparations and compounds of formaldehyde are:

Aminoform, Ammonio-formaldehyde—synonyms for hexamethylene-tetramine.

Amyloform—starch and formaldehyde (see Vol. I.).

Bismal—the bismuth salt of methylene digallic acid, formed by the action of gallic acid on formaldehyde. Used as intestinal antiseptic and astringent.

Creoform, Creosoform, Kreoform—a non-toxic, tasteless, and odorless compound of creosote and formaldehyde. A strong antiseptic.

Cystamine, Cystogen—synonyms for hexamethylene-tetramine.

Dextroform—formaldehyde and dextrin (see *Amyloform*, Vol. I.).

Eka-iodoform—iodoform and paraformaldehyde (see Vol. III.).

Euformol is a mixture of oil of eucalyptus, formaldehyde, thymol, menthol, etc.

Formacoll—synonym for glutol.

Formaldehyd-bisulphite (HCOH, $Na_2S_2O_5$) is a crystalline mixture resulting from the action of formaldehyde on sodium bisulphite in solution. It is claimed to possess the antiseptic properties of both constituents.

Formaldehyde-casein (Formalbumin) is an odorless, tasteless, coarse yellow powder, used in surgery as an antiseptic.

Formaldehyde-gelatin—used in photography and in surgery (see *Glutol*).

Formaldehyde-sulpho-carbolic acid $[(CH_2OH)_2.C_6H_3.OH]$ is used as an antiseptic dressing for wounds.

Formaldehyde tannalbuminate—tannalbumin subjected to the action of formaldehyde to render it more resistant to the action of the gastric juice. The compound passes unchanged through the stomach, and as it is split up but slowly in the intestines, it gets well down in the bowel before it separates into its components. Used as an intestinal antiseptic and astringent.

Formaldehyde-urea is an amorphous, white condensation product of urea and formaldehyde in alkaline solution. It is insoluble in water. Used as disinfectant.

Formalin, Formol—a saturated aqueous solution of formaldehyde.

Formatol is a proprietary dusting powder containing formaldehyde.

Formin—synonym for hexamethylene-tetramine.

Formo-chloral is an oily compound formed by the action of formaldehyde on chloral in the presence of concentrated sulphuric acid. It is used as an antiseptic.

Another compound of this name, used by Trillat as a deodorizer, is made by acting with calcium chloride on formaldehyde in solution in methyl alcohol.

Formoforin consists of formaldehyde 0.18, thymol 0.10, zinc oxide 34.44, and starch 65.28 per cent., and is used for sweating of the feet.

Formopyrin occurs in white crystals formed by the action of formalin on a solution of antipyrin. It is insoluble in cold water or ether, but fairly soluble in boiling water, alcohol, chloroform, and acids, with the latter forming stable salts.

Fortoin—cotoin acted upon by formaldehyde (see *Fortoin*).

Galloformin is prepared by acting on hexamethylene tetramine with gallic acid (see *Galloformin*).

Geoform—guaiacol and formaldehyde (see *Geoform*).

Glyco-formol is a mixture of formalin, water, and glycerin.

Glycero-formol is said to be formed by the prolonged action of formaldehyde on glycerin. It is claimed to be more toxic than formaldehyde, but the writer could find no evidence for this statement.

Hexamethylene-tetramine—the chemical name for aminoform, cystamine, cystogen, formin, and urotropin (see Urotropin).

Holzin is a sixty-per-cent. solution of formaldehyde in methyl alcohol used by Oppermann as a deodorizer.

Holzinol is a mixture containing formaldehyde and menthol.

Krameroform is prepared like tannoform, but from rhatany-tannin.

Lanoform is lanolin containing one per cent. of formaldehyde.

Lysoform is a soapy disinfectant containing formaldehyde (see *Lysoform*).

Naphthoformin is made from paraformaldehyde and the alpha and beta compounds of naphthol. It is used both externally and internally as an antiseptic.

Paraform is paraformaldehyde.

Polyformin Soluble and Insoluble—used in skin diseases (see *Polyformin*).

Preservalin—a mixture used by dairymen.

Protogen is an albuminous food obtained by acting on serum or egg albumen with formaldehyde. It is not coagulated by heat.

Quebrachoform, Quinoform, Querciform are prepared like tannoform (which see), but from the tannins of quebracho, cinchona, and oak.

Saligenin, also yielded by salicin, may be obtained by the interaction of phenol and formaldehyde.

Steriform Chloride and *Iodide*—formaldehyde 5, pepsin 20, lactose 65, and ammonium chloride or iodide 10.

Tannoform—an antiseptic in skin diseases (see *Tannoform*).

Tannopin or *Tannon* consists of tannin and hexamethylene-tetramine, and is used in diarrhœa (see *Tannopin*).

Thymoform is thymol-formaldehyde (see *Thymoform*).

Triformol, Trioxymethylene—synonyms for paraformaldehyde.

Urotropin—hexamethylene-tetramine (see *Urotropin*).

W. A. Bastedo.

FORMANILID ($C_6H_5NH.COH$) occurs in long, colorless prismatic needles obtained by digesting aniline with formic acid, or by rapidly heating aniline and oxalic acid together. It melts at 46° C. (115° F.), and is soluble in water, alcohol, glycerin, and oils. In dose of 0.13–0.3 gm. (gr. ij.–v.) it is antipyretic and analgesic, but is said to depress the heart and produce cyanosis. Its chief employment is as a local anæsthetic in two-per-cent.

solution, as in genito-urinary inflammation, or subcutaneously, or in powder form, mixed with chalk, starch, or talcum, or as a snuff in nasal troubles. *W. A. Bastedo.*

FORMIC ACID.—$HCHO_2$. Formic acid is a heavy, colorless fluid of a sharp, sour odor and taste, soluble in all proportions in water, alcohol, and glycerin. It is exceedingly irritating, producing, when applied to the skin, redness, blistering, and even sloughing, and, taken internally, gastro-enteritis and bloody urine. It has been used occasionally, locally, as a counter-irritant, applied diluted with an equal measure of water.

Edward Curtis.

FORT CRAWFORD MINERAL WELL.—Crawford County, Wisconsin.

Post-Office.—Prairie Du Chien. Hotel.

Access.—Viâ Chicago, Burlington and Quincy, and Chicago, Milwaukee and St. Paul Railroads. Prairie du Chien contains about 4,000 inhabitants, and is one of the oldest towns in the State. The well from which the mineral water is obtained was bored in 1876. At a depth of 960 feet a strong flow of water was encountered, and ever since there has been a continuous stream, six inches in diameter and having a pressure of twenty pounds to the square inch. The well yields about 40,000 gallons per hour. By means of mains and hydrants it furnishes the city fire department, and affords an abundance of water for domestic purposes. It was soon learned that the water possessed medicinal qualities. An analysis by Professor Bode, of Milwaukee, showed the following results:

One United States Gallon Contains:

Solids.	Grains.
Calcium bicarbonate	0.62
Magnesium bicarbonate	10.97
Sodium chloride	90.20
Potassium chloride	3.80
Sodium bromide	.13
Sodium sulphate	12.80
Calcium sulphate	15.38
Iron bicarbonate	.23
Sodium phosphate	Trace.
Sodium bicarbonate	Trace.
Alumina	.66
Silica	3.84
Organic matter	None.
Total	138.63

This is a valuable member of the widely useful alkaline-saline class of waters. It closely resembles some of the Saratoga waters in its mineral constituents, being, however, somewhat milder than those waters. Its chief effects are antacid, laxative, diuretic, and tonic. It is well adapted for the class of diseases to which such waters are applicable. It is also an excellent table water. A well-equipped sanitarium with ample bathing facilities is conducted in connection with the well. The water is used commercially. *James K. Crook.*

FORTOIN, or methylene-dicotoin [$CH_2(C_{14}H_{11}O_4)_2$] is obtained by allowing formaldehyde to act on cotoin, and occurs in yellow, tasteless crystals or powder having a cinnamon-like odor. It melts at 211°–213° C. (412°–415° F.), is insoluble in water, soluble with difficulty in alcohol, ether, and benzol, and readily soluble in chloroform, acetone, glacial acetic acid, and alkalies. Overlach reports thirty cases of diarrhœa in which it was used in dose of 0.25 gm. (gr. iv.) three times a day as an intestinal astringent. He believes it preferable in cases with sloughs of the mucous membrane of the intestine, as, unlike the tannin preparations, it stimulates tissue growth and causes regeneration of the mucous membrane. Its advantages over cotoin are that it is free from pungent taste and is a more powerful bactericide. *W. A. Bastedo.*

FOUNTAIN PARK MAGNETIC SPRINGS.—Champaign County, Ohio.

Post-Office.—Fountain Park. Hotel and cottages.

Access.—Viâ Pennsylvania Railroad (P., C., C. and St. L., Indianapolis Division). The hotel is within five minutes' drive of the Fountain Park Station. The location is 34 miles west of Columbus and 12 miles east of Urbana. Fountain Park village was laid out in 1882 soon after the discovery of the springs. The resort came under the present management in 1894. The site of the village is one of great natural attractiveness. The elevation is 1,200 feet above the sea-level and the surrounding country is gently undulating. The hotel and cottages are located in a beautiful tract of 43 acres in which are numerous hills surmounted by groves of deciduous trees. New acme stone walks and driveways have recently been laid around the hotel grounds, and an artificial lake of sufficient size for boating constructed. The large lawn is adapted for all kinds of outdoor sports and games. Brush Lake, one mile east of the Park, affords rare attractions to the piscatorially inclined visitor. The waters at Fountain Park proceed from five flowing wells. The largest is 2,200 feet in depth and fills a ten-inch pipe at about twenty-one pounds' pressure. Following is an analysis of this spring, made in 1892 by Prof. E. S. Wayne, of Cincinnati:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	13.64
Calcium chloride	4.22
Magnesium chloride	2.12
Potassium sulphate	2.61
Calcium carbonate	26.24
Magnesium carbonate	11.41
Iron carbonate	.16
Silica	.24
Organic matter	.39
Total	61.03

This is an excellent water of the alkaline-saline-calcic variety. The presence of a small quantity of carbonate of iron will prevent debilitating effects on continuous use. The water has been found valuable in acute and chronic rheumatism, gout, dyspepsia, and diabetes. Two of the remaining four wells were analyzed in 1895 by Prof. H. A. Weber of the Ohio State University. They show the same general characteristics as Spring No. 1 (above). There is an excellent modern hotel in the Park. It contains twenty well-equipped bath-rooms, under the charge of an experienced physician. *James K. Crook.*

FOXGLOVE. See *Digitalis.*

FRACTURES.—A fracture is the breaking of a bone or of a cartilage. The sudden forcible destruction of the continuity of a bone in whole or in part, except when done with a cutting instrument, is called a fracture (Stimson). The gradual undermining of the strength of a bone, whether by tumor or by inflammation, does not produce a fracture until a trauma, however slight, snaps the diseased bone. The so-called *pathological* fractures are of this class. The trauma may be so slight as to pass unrecognized, but, nevertheless, this "sudden, forcible destruction of continuity" constitutes the fracture. The only etiological difference between pathological and traumatic fractures is that in the former the disease of the bone predisposes it to fracture and the violence required to produce the fracture is comparatively insignificant.

Varieties.—Fractures are commonly classified as complete and incomplete.

A Complete Fracture is a break traversing the whole thickness of a bone. In a long bone, this implies that the extremities of the bone are separated by the line of fracture. In a flat bone a complete fracture may simply break off a fragment.

Incomplete Fractures may be: (1) Fissured; (2) "Greenstick"; (3) Depressed; (4) Separation of a splinter or of an apophysis.

By a "depressed" fracture is here meant a depression of only part of the thickness of a flat or long bone. It is not an uncommon fracture of the cranial bones.

The commonest of all incomplete fractures is the *green-*

stick fracture (infraction). It usually occurs in the forearm or clavicle, and is rarely seen in adults. The condition of the bone is exactly that of a green stick broken over the knee (Fig. 2200). The bone is bent and on its convexity broken, the line of fracture running inward, transversely or obliquely, and then longitudinally in either or both directions.

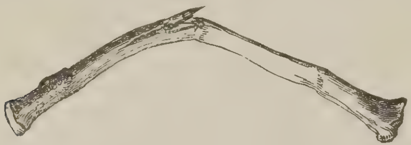

Fig. 2200.—Green-stick Fracture.

Fractures are usually described according to—

(*a*) Their direction, as tranverse, oblique, longitudinal, toothed (dentate), etc. (Figs. 2201, 2202, 2203).

(*b*) The seat of fracture—of the shaft, neck, epiphysis, condyle, epiphyseal separation, etc.

(*c*) Special features—simple, compound, comminuted, impacted, multiple, gunshot, pathological, intra-articular, etc.

A *simple* fracture is one neither compound nor comminuted. A *compound* fracture is one in which the external wound runs down to the seat of fracture. A *comminuted* (Fig. 2204) fracture is one in which the bone is splintered into a number of small fragments. By *multiple* fracture is meant the fracture of several bones or of the same bone in several distinct places. Simple fracture of both bones of the forearm or leg, however, is not spoken of as a multiple fracture. An *impacted* fracture is one in which the broken bone ends are crushed into each other and thus fixed more or less firmly.

Etiology.—*Frequency.*—Men are more subject to fractures than women (three to one), by the nature of their occupations, and their habits of life. Stimson disagrees with the accepted belief that fractures are most frequent during the winter months on account of the ice and snow, the increased frequency of fracture of the lower extremity in winter (seventy-six to fifty-three) being more than offset by the increased frequency of fractures of the upper extremity in summer (one hundred and seven to sixty-seven.)

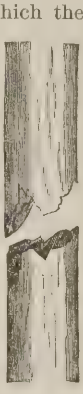

Fig. 2201.—Toothed Fracture of the Femur.

Fractures are relatively more frequent in the aged than in the adolescent (Malgaigne, Gurlt), and this in spite of the greater exposure of the latter class to various injuries. This increasing liability to fracture with age is due to a progressive decrease in agility and strength of muscle with which to ward off or minimize an injury, and also to certain changes that take place in the bones themselves.

Predisposing Causes.—In infancy the structure of the bones is in great part cartilaginous, the bones are elastic, and fracture is rare. In adult life the cartilage is replaced by bone; hence a loss in elasticity and an increase in strength; fractures are more frequent. Later still, when senile changes occur in the body, the bones become thinned by an actual diminution in the amount of bone tissue and a corresponding increase in the contained fatty and connective tissue. The bone becomes weak and brittle, and in spite of the lessened exposure to injury, fractures are most frequent. The luxations of elbow and hip, for example, are in great part replaced by fracture of the humerus, and neck of the femur, the latter being, *par excellence*, the fracture of old age.

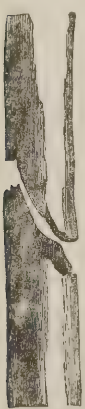

Fig. 2202.—Oblique Fracture.

Pathological predisposing causes of fracture are disease of the bone, such as gumma, sarcoma, osteomyelitis, and necrosis. The condition known as osteoporosis is a rare cause of fracture. In this disease the bones appear to have undergone in early life the rarefying process natural in old age. Diabetes, paralysis, locomotor ataxia, osteomalacia, and pregnancy have been noted as causes of this condition. The resulting brittleness of bone is often so marked that many fractures occur almost simultaneously. Such fractures usually heal perfectly well. Prolonged disuse may apparently cause osteoporosis, and some cases are congenital.

Immediate Causes.—A fracture is always caused by some force, external or internal. (1) Fracture by external violence. (2) Fracture by muscular action.

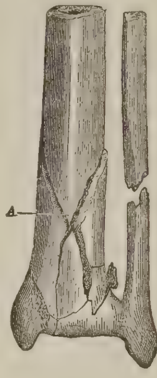

Fig. 2203.—V-shaped Fracture.

The mechanism of fracture by external violence is usually simple enough. The bone is crushed, broken or twisted, or a fragment is torn away from it. The fracture may be *direct* or *indirect*. A direct fracture occurs at the point of impact, an indirect one by transmission of the force to some more or less distant point. Thus a fall upon the outstretched hand may result in a direct fracture of the carpus, metacarpus, or phalanges, or an indirect fracture of radius, ulna, humerus, or clavicle. This distinction is most important only in compound fractures.

Muscular action is concerned in almost every fracture. Indeed the drunken man who uses his muscles little or not at all is notoriously shielded by a special Providence in this matter. But by "fracture by muscular action" is meant those fractures caused solely by muscular action. The commonest of these is fracture of the patella.

Spontaneous and *pathological* fractures have already been considered.

Pathology.—When a bone is broken the condition is a laceration of the bone itself, the periosteum, and, to a greater or less degree, of the surrounding tissues.

The bone is broken more or less completely, splintered or comminuted (see Varieties). The periosteum is usually torn in one or more places, and is elsewhere stripped up from one or both fragments, while remaining attached to each and forming a bridge between them. This *periosteal bridge* is of great service in the process of repair.

The damage to the soft parts, if caused by the broken ends of the bone ploughing through them, constitutes a complication of the fracture, while if the fracture is simply one of a number of lesions due to a trauma, the condition of the bone is relatively unimportant. This distinction has no weight in fractures of the extremities where bone lesions are always of primary importance; but in injuries of the skull and thorax an undue prominence is often ascribed to the bone lesion and injuries of the contained viscera are classed as complications of fracture; whereas the presence or absence of fracture has often little or nothing to do with the etiology, prognosis, or treatment of the visceral injury.

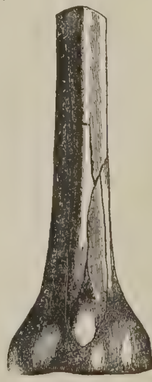

Fig. 2204.—Comminuted Fracture.

The laceration of the skin may, like that of other soft parts, be caused directly by the trauma or indirectly by the protrusion of a fragment of bone either by laceration or sloughing. Here, again, the distinction is of importance. If the fracture is compounded at the seat of injury the wound is usually large and plentifully befouled, while if indirectly compounded by puncture or sloughing over a sharp point of bone, the skin wound is comparatively small and clean; the probability is that it will escape infection, and as a compound fracture it is comparatively unimportant.

Process of Repair.—Within the first few hours after a fracture has been received the contusion and laceration of the various tissues produce a hæmatoma and then œdema. This œdema increases for twenty-four or forty-eight hours and then gradually subsides. The application of moist heat and pressure to the limb minimizes the œdematous reaction and hastens its resorption. During this period, the periosteum like the other tissues is boggy and thickened, and the bone ends lie in a cavity of greater or less size, full of semi-coagulated blood. As the œdema disappears, granulations spring from the periosteum, the surrounding soft parts, the marrow, and the bone itself. At the same time the blood collection disappears, partly by absorption and partly by making its way along the various fascial planes whence it may finally reach the surface, forming an ecchymosis some days after the injury and thus constituting one of the signs of fracture.

Thus the process of repair begins by simple granulation of all the lacerated structures, and it may be said to have completed its *first stage* when these granulations, spreading along the periosteal bridge or simply filling the cavity between the bone ends, completely envelop the region of fracture in a mass of granulation tissue. This mass is called the provisional callus. Its shape and size, as well as its relation to the bone ends, depend on the amount and nature of the displacement. If this is slight the callus is small; if considerable, it is large and irregular. This callus is formed chiefly by granulations springing from the periosteum (Fig. 2206), and in a less degree from the marrow, and also by a thickening of the periosteum and by granulations from the soft parts and the bone ends. The greater part of the callus, that arising from the periosteum, first changes to cartilaginous tissue and then to bone; the callus formed from the marrow goes through no cartilaginous formation, but becomes bone directly, the osseous formation beginning around the inner surface of the bony shell and extending inward until it entirely occludes the medullary canal (medullary plug), and outward to meet the periosteal callus and the medullary plug of the other fragment.

By this time, toward the end of the third or fourth week, the healing of the soft parts is complete, the ecchymoses are disappearing, and the callus, composed of bone within and cartilage and bone without, is quite firm everywhere except over the broken edges of the fragments. The delay here is due to the very slow progress of bone granulation, partly because of the comparatively poor circulation of that tissue and partly because a thin shell along the surface of the bone is cut off from the circulation and has to be absorbed, as have also the splinters which must inevitably be torn away at the time of fracture, before the callus can unite firmly to the bone itself. This concludes the *second stage* of the process of repair.

The osseous callus now unites the bone ends very much as a mass of solder connects two ends of pipe, with this important difference, however, that the callus is a solid mass obstructing the lumen of the "pipe" as well as extending beyond its circumference. In the *third and final stage* of repair the superabundant callus is gradually absorbed. The lumen of the bone is cleared, the callus between the bone ends becomes firmer and more compact, approaching in structure very nearly to that of the bone ends which it connects, and the external callus is absorbed until in some cases, when the bone has been accurately "set," there remains no trace of the fracture. Thus the reparative process is completed months after the receipt of injury. In most cases, however, the reduction of the fracture is not and cannot be absolutely accurate, and in these cases the displaced bone is fortified by a permanent exuberance of callus which persists during the life of the subject. At the same time projecting edges of displaced bone are rounded off in the process of callus absorption. If the exuberant callus invades a joint cavity or surrounds a nerve, ligament, or tendon, the chisel may be required to reduce it.

The fate of completely detached fragments of bone is interesting. Small splinters are probably always absorbed, but, judging from the appearance of old fractures, it is probable that fairly large fragments may become embedded in the granulations, derive new circulation from them, and end by forming an important element in the reconstructive process. On the other hand, fragments may remain embedded but unattached to the callus for years, and their presence be first suspected when, on account of debility or inflammation elsewhere in the organism, they become centres of suppuration which go on to abscess and fistulization and persist until the offending fragment is removed.

In fractures of the skull the repair is chiefly effected by the diploë which is not capable of producing exuberant callus or of closing in large defects, such as those left by a trephine opening.

Fracture of spongy bones or of the spongy ends of long bones is repaired chiefly by the bone itself. Fracture of cartilage is slow to heal and the union is chiefly fibrous. Hence old fractures crossing a joint surface are usually marked by a line of fibrous tissue or bare bone where the cartilage has been lacerated, though in exceptional instances the callus is exuberant.

The histological processes of callus and bone formation and resorption are quite the same as take place in the normal growth of a bone.

The repair of a compound fracture differs in several ways from that of a simple fracture. In the first place the primitive œdema and hæmatoma are less on account of the free escape allowed to the blood and serum. A more important difference, however, lies in the result of infection. If the wound suppurates, healing is delayed by the casting off of all fragments, by the death of a layer of some thickness along the broken edge, and especially by the destruction of the periosteum. The bone is reformed entirely by the medullary plug which grows slowly (and does not undergo immediate cartilaginous formation). The callus is large and irregular and fragments of dead bone caught within it may prolong the suppuration indefinitely.

Symptoms and Diagnosis.—The symptoms of fracture are subjective and objective. The subjective symptoms are the history, pain, tenderness, and loss of function. The objective signs are deformity, abnormal mobility, crepitus. It is usually one or more of the subjective symptoms that lead to the suspicion of fracture, while it is upon the objective signs that the diagnosis is based.

Subjective Signs.—The *history* of the patient may relate to previous fractures which have left a deformity that might otherwise be misleading. A history of active syphilis affects the prognosis and treatment. In old fractures the history may be of valuable assistance, though in recent cases it is usually indefinite and unreliable.

Pain and tenderness are constant symptoms of fracture unless the patient is intoxicated, comatose, or suffering from some grave lesion of the central nervous system. Spontaneous pain is usually diffuse and referred rather to the point of greatest contusion than to the point of fracture. Thus in Pott's fracture, the pain is often greatest over the inner side of the joint, though the chief lesion of the bone is in the other side. Tenderness is, however, a more definite symptom. It is usually localized over the point of fracture and may be a great aid in establishing this point accurately. This is especially the case in fracture of the ribs and fibula (*q. v.*). It is a universal rule that *when pressure applied laterally or in the long axis of a bone evokes pain at a distance from the point where the pressure is applied there is a fracture at the painful point.*

Loss of function may be considerable or slight. When the shaft of a long bone is broken function is lost in most instances. Yet the loss of function is in part due to pain and fright, and hence varies with the nervous quality of the patient.

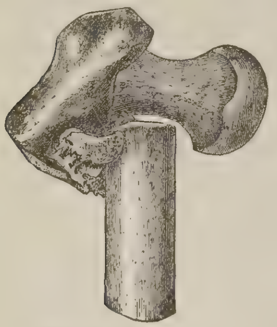

FIG. 2205.—Fracture of the Shaft of the Femur. Overriding and angular displacement; faulty union.

OBJECTIVE SIGNS.—Without the objective signs the diagnosis of fracture is never certain. They are essential. The objective signs of contusion or laceration of the soft parts, always present in greater or less degree, sometimes (*e.g.*, compound fractures) facilitate the diagnosis, but more often only obscure the objective signs of the fracture itself.

Deformity.—The deformity caused by fracture is the result of injury to the soft parts as well as of displacement of the broken bone. In some fractures the bone deformity is characteristic and unmistakable, but it is too often obscured by the effusion of blood and consecutive œdema to be a symptom readily determined by simple inspection. Hence the four methods of determining the existence of deformity, *viz.*, inspection, palpation, mensuration, and the *x*-rays.

The deformity is caused by displacements of the broken ends of the bone. The displacement may be slight or great, characteristic or obscure; hence the variety of means adopted to recognize it. Malgaigne has classified displacements as transverse, angular, rotary, overriding, impaction or crushing, and rarest of all, direct longitudinal separation. Clinically the displacement may come under two or more of these classes (*e.g.*, overriding and angular) (Figs. 2205, 2206).

Inspection may suffice to determine the existence of displacement. *Palpation* may determine the angular deformity of a bone or the protrusion of sharp fragments close under the skin; but abnormal motility and crepitus (*q. v.*) are *par excellence* the data sought by palpation.

Mensuration, on the other hand, is often of great service in the estimation of deformity, for whether impacted or overriding, the broken bone is usually shortened by muscular tension and swelling, the increase in circumference of the member being compensated for partly by shortening and partly by the elasticity of the integument. However obscured the deformity at the point of fracture, the shortening of the bone may be estimated by comparing its length with that of its fellow of the opposite side. In applying mensuration, however, two most important facts must be borne in mind:

1. There may be a previous difference in length, either congenital or acquired, of the two bones.
2. In comparing the length of the long bones of a limb it is often necessary to measure from bony points not on the same bone. In this case the bones to be compared must be in the same relative position.

In other words, if the injured limb is measured in the abducted or flexed position, the measurements of the uninjured member must be taken with it *at the same angle* of abduction or flexion. Neglect of this simple precaution is often a grave source of error in estimating shortening from fracture of the neck of the femur. The measurements are usually taken from the anterior superior spine of the ilium to the external malleolus, and the injured limb, whether fractured or not, usually lies slightly abducted and flexed, while the patient instinctively protects it by adduction of the sound limb. The relative positions of the limbs cannot be appreciated unless the patient is laid flat on his back and stripped so that the two anterior superior spines can be distinctly felt. A string drawn tightly from one to the other marks the horizontal plane of the body, and a perpendicular dropped from the centre of this marks the sagittal plane with which the abducted thighs should make equal angles.

Measurements of the diameter or the perimeter of the limb are entirely fallacious.

Abnormal Mobility and Crepitus.—These two symptoms might be termed the accessory symptoms of fracture. When obtainable there is nothing more characteristic of fracture than abnormal mobility along what should be the firm shaft of a bone, especially if accompanied by a grating sensation of crepitus imparted to the fingers rather than to the ear of the surgeon as the rough bone ends are made to rub against each other. But while these two signs are more frequently sought for than any other of the signs of fracture, they may be misleading and non-essential to a complete diagnosis, and the search for them is often the occasion of rough and painful manipulations injurious both to the patient's tissues and to his mental attitude toward the surgeon. In this matter gentleness is far more successful than force, for force assures the resistance of the patient's muscles at the same time as it blunts the sensitiveness of the surgeon's fingers. The methods of eliciting abnormal mobility and crepitus are two; (1) pressure; (2) passive motion.

Pressure is usually applied transversely to one or alternately to each of the fragments with the intent of making them slip by each other. Passive motion, angular or rotary, is employed for the purpose of demonstrating that one fragment (or some bony prominence upon it) is unaffected by motion communicated to the other.

The commoner causes of error are impaction which prevents both abnormal mobility and crepitus, the interposition of soft parts which prevents crepitus or the existence of that form of fracture known as epiphyseal separation, in which crepitus is cartilaginous. Moreover, in injuries about a joint abnormal mobility may indicate either fracture or dislocation, perhaps both, and the rule that "in fracture there is mobility where before there was none, while in dislocations abnormal mobility in one direction is compensated by restricted mobility in other directions," may not be practically applicable.

X-Rays.—The report of the committee of the American Surgical Association defines very accurately the present status of the *x*-rays in the diagnosis of fractures. Among their conclusions are the following:

1. The routine employment of the *x*-ray in cases of fracture is not at present of sufficient definite advantage to justify the teaching that it should be used in every case. If the surgeon is in doubt as to his diagnosis, he should make use of this as of every other available means to add to his knowledge of the case, but even then he should not forget the grave possibilities of misinterpretation. There is evidence that in competent hands plates may be made that will fail to reveal the presence of existing fractures or will appear to show a fracture that does not exist.

2. In the regions of the base of the skull, the spine, the pelvis, and the hips, the *x*-ray results have not as yet been thoroughly satisfactory, although good skiagraphs have been made of lesions in the last three localities. On account of the rarity of such skiagraphs of these parts special caution should be observed, when they are affected, in basing upon *x*-ray testimony any important diagnosis or line of treatment.

3. As to questions of deformity, skiagraphs alone, without expert surgical interpretation, are generally useless and frequently misleading. The appearance of deformity may be produced in any normal bone, and existing deformity may be grossly exaggerated.

4. It is not possible to distinguish after recent fractures between cases in which perfectly satisfactory callus has formed and cases which will go on to non-union. Neither can fibrous union be distinguished from union by callus

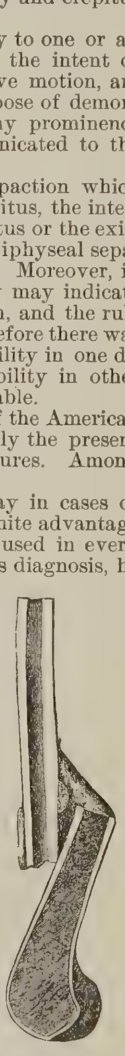

FIG. 2206.—Malunion after Fracture of the Shaft of the Femur. Shows callus formation under periosteal bridge.

in which lime salts have not yet been deposited. There is abundant evidence to show that the use of the *x*-ray in these cases should be regarded as merely the adjunct to other surgical methods, and that its testimony is especially fallible.

DIAGNOSIS.—In general the diagnosis of fracture is made by inspection and gentle palpation, aided perhaps by mensuration. Most of the commoner fractures are marked by a characteristic deformity, or by some other pathognomonic sign.

In compound fractures the diagnosis should be made with as little probing as possible. If the wound is small and clean it should be drained or sealed after it has been thoroughly irrigated, and the diagnosis made as in simple fracture. If, however, the wound is wide and befouled, the diagnosis of the exact nature of the fracture is readily determined in the course of the preliminary antiseptic toilet.

Young persons up to the age of twenty-five present two special points of diagnosis. In the first place, when they receive a fracture through the extremity of a long bone, it is very likely to follow the line of least resistance along the unossified cartilage between the diaphysis and epiphysis, thus forming an *epiphyseal separation.* The diagnosis of this condition is made on three data: first, the correspondence of the line of fracture either wholly or in greater part with the line of the epiphyseal cartilage; second, the "muffled" cartilaginous crepitus obtained when the bone ends are drawn across each other; and third, the subsequent atrophy of the torn cartilage often resulting, unless the bone has attained its full growth, in a shortened deformed limb. The most important epiphyseal separations are those of the upper extremity of the humerus and the lower extremity of the radius, since these injuries are comparatively common and these epiphyses together are responsible for two-thirds of the growth of the upper extremity. The second point of importance in the diagnosis of fracture in young persons is the frequency of incomplete fractures. The *green-stick* fracture, practically unknown in the adult, occurs with comparative frequency in the young as a result sometimes of a slight trauma. If the break is insignificant the only clinical evidence of it is an abnormal protuberance of the shaft of the bone. This may pass for a mere contusion, especially if the superficial tissues are considerably bruised. Such fractures are unimportant since they require no attention and have no more consequence than an outgrowth of callus which is absorbed in the ensuing months. More severe "green-stick" fractures produce a curving or angular deformity of the bone and a considerable protuberance of the split fragment, so that the diagnosis is not difficult.

DIFFERENTIAL DIAGNOSIS.—A fracture must be differentiated on the one hand from a dislocation, and on the other from a sprain or bruise. In either case the confusion is likely to arise only in the region of a joint, where, from the slight deformity, the difficulty in eliciting crepitus and abnormal mobility, and the unimportant interference with function (*e.g.*, many Colles' and some Pott's fractures), the injury may be mistaken for a sprain; or because of the great swelling of the soft parts all landmarks may be obscured. In such a contingency, if an accurate diagnosis cannot be reached by the aid of the ordinary data, an examination should be made with the patient anæsthetized, or, better still, if the apparatus is at hand, the *x*-rays may be employed.

PROGNOSIS.—If a fracture is properly reduced and immobilized, the primary inflammatory reaction may be expected to subside in from three to ten days. During this period there is more or less discomfort; but later physiological rest and a comfortable splint may be depended upon to relieve the patient of almost all his pain. The amount of rest required depends upon the nature of the injury and the individuality of the patient. The laboring man who insists upon walking off on an ambulatory splint two days after he has received a Pott's fracture is not to be classed with the neurasthenic woman whom the same injury confines to her room until long after the bones have united. Immobilization is almost as unimportant in the treatment of Colles' fracture as it is essential in fracture of the patella.

Age affects the prognosis in that metabolism is less rapid in the aged; their bones heal more slowly and their confinement to bed may result in bed sores and permanent debility; while if they escape this, a permanent stiffening and neuralgic condition of the affected limb may result. In the young the prognosis of simple fracture is entirely good, unless there is epiphyseal separation.

Habits and *disease,* such as alcoholism, syphilis, and general debility, affect the prognosis in proportion to their severity. The shock of fracture will often bring on delirium tremens in an alcoholic subject. Such an attack may sometimes be averted by getting the patient up and about immediately, in addition to the usual therapeutic measures. Syphilis in an active stage may delay or prevent union in a broken bone, and any chronic debilitating disease may have a similar effect.

Certain qualities of the fracture itself must be considered in the prognosis. For example, the prognosis in *compound fractures* is far graver both as to life and limb than that of simple fracture. Indeed, what with the dangers of suppuration, septicæmia, delayed and malunion, it is almost impossible to give an accurate prognosis for a compound fracture until healing is well advanced. Again, *fractures of spongy bone* heal far more rapidly than fractures of the shaft. But, on the other hand, the spongy bones lie chiefly in the region of joints, and if these are invaded by the callus, or even if merely immobilized during the process of repair, the stiffness resulting from prolonged inaction may indefinitely delay complete recovery. Indeed, the union of the bone is only the skeleton of the cure as far as the patient is concerned. When the bones are sound he is "set upon his feet," but it may be weeks before he is "limbered up" enough to accomplish anything but the lightest labor. In this connection Loew's figures are instructive and represent a most successful series. Of 167 simple fractures of the leg, one was permanently disabled, and the others were able to return to work in an average of one hundred and one days (seventy per cent. of them in ninety-one days), more than twice the classical limit assigned to the healing of a fracture of the leg. In this matter of regaining function, age is of prime importance. The young and vigorous regain both strength and agility in a few weeks, while the aged and rheumatic remain stiffened and more or less completely decrepit. The joint implicated also makes a difference. The fingers and toes are especially liable to stiffening when extended. Other elements in the prognosis are afforded by the complications.

COMPLICATIONS.—The pain, œdema, and contusion of the soft parts during the first days, and the later stiffening of the joints, occur as complications to almost every fracture, however normal the process of repair, and they have therefore been described above. The remaining complications may be early or late, local or general.

Among the *early local complications* the most important are the laceration of the soft parts producing a compound fracture, penetration of a joint by the line of fracture, and fracture dislocation.

A *compound fracture* may be direct or indirect. Direct compound fracture occurs when the trauma causing the fracture tears open the soft parts surrounding the bone. Indirect compound fracture is caused by the protrusion through the skin of one of the fragments, perhaps at some distance from the point of injury. This may be due to displacement at the time of fracture or during the subsequent manipulation or transportation; or it may occur later by sloughing of the tissues over a sharp fragment on account of faulty splints. The distinction between direct and indirect compound fractures has an important bearing on the prognosis and treatment. In the former class the wound is often gaping, irregular, and befouled; wherefore the prognosis is bad and the primary antisepsis must be thorough. In the latter the small, clean wound may often be cleansed by superficial antisepsis, without disturbing the deeper tissues.

Fractures implicating joints, *intra-articular fractures,* imperil the integrity of the joint both by displacing the articular surfaces and by the production of callus which may invade the joint cavity and impede its motion or even unite the opposing articular surfaces by fibrous or bony union, thus altogether preventing motion.

Fracture dislocation is often a very serious condition. The various fracture dislocations will receive special mention.

Other early local complications are laceration of a nerve, gangrene from rupture, thrombosis or occlusion of vessels, profuse, even fatal hemorrhage through laceration of a large vessel, and traumatic or arterio-venous aneurism from the same cause. Gangrene and muscular contracture from improper splinting are complications of the treatment rather than of the fracture itself.

Suppuration and septicæmia, so common in direct compound fractures, are rare otherwise. *Fat embolism* is most exceptional. In the first days after fracture, fat globules may sometimes be found in the urine. Of exceptional occurrence are the cases in which within twenty-four or forty-eight hours of the injury the patient is suddenly overcome with dyspnœa and dies sometimes with symptoms of pulmonary embolism, sometimes with œdema of the lungs, sometimes with predominence of symptoms from the central nervous system, unconsciousness, paralysis, convulsions. On autopsy the pulmonary or cerebral capillaries are found occluded by minute globules of fat, derived, it is presumed, from the bone marrow. Opinions differ as to how much influence fat embolism has in the production of "delayed" shock, and irregular "delirium tremens" occurring within the first few days after fracture. *Delirium tremens* and *pneumonia* are not infrequent complications of fractures in alcoholic subjects, both on account of the shock and the confinement to bed. Either condition is a very grave one coming on during the first week and often terminating fatally.

The *late complications* of fracture are all local. Persistent pain of a rheumatic, gouty, or neuralgic character, atrophy of the muscles from disuse, arrest of development in the bone after epiphyseal injury, and stiffness of the joints from prolonged immobilization have already been alluded to. Permanent atrophy and paralysis may result from rupture of a nerve, and permanent neuralgia from the inclusion of a nerve within the callus. There is always some œdema when the limb is first allowed to hang down. This is transitory, however, unless maintained by other causes.

The callus may be painful, excessive, or weak. Pain localized in the callus is rare and suggestive of threatening suppuration, inclusion of a nerve, or hysteria. That the callus should be excessive at first is not abnormal nor is it to be expected that a small callus will suffice to weld two widely separated or widely displaced fragments. Indeed, except from an æsthetic point of view, excessive callus is not a complication unless it produces pressure on some vital structure or impedes the action of a joint or muscles. In such a case recourse must be had to the chisel, but only after several months of massage and motion have proven that resorption is not to be expected. Pathological weakness in the callus—weakness, namely, after the time necessary for consolidation has elapsed—is unusual except from considerable displacement, from compound fracture in which suppuration has occurred, or from systemic debility or disease. Primary sarcoma and secondary carcinomatous deposits have very rarely been observed after fracture. Weakness of the callus produces the condition known as delayed union.

Delayed union (failure of union, pseudoarthrosis) is that condition in which the callus uniting a fracture fails either wholly or partially to ossify, so that the fragments are connected by a mass or band of fibrous tissue, or rarely by a distinct joint.

From this definition must be excepted certain fractures, such as those of the patella, the olecranon, and other apophyses, in which bony union is unusual and unessential. A theoretical distinction may be made between delayed union, in which union is still possible, and failure of union in which it is not. But it is never certain in any given case that union is impossible unless years have passed from the time of the injury, and hence the more hopeful term is preferable.

The causes of delayed union have been briefly enumerated above. Although every form of lowered vitality has been incriminated, local conditions are to blame in the great majority of cases. Either the fracture is a "pathological" one, in which case the "pathological" factor must be removed before union can be expected, or the bone ends have not been kept in apposition, on account of faulty immobilization, the interposition of the soft tissues between the fragments, or the interposition of a considerable amount of comminuted bone detached from its periosteum. A common cause of delayed union is suppuration, notably in compound fractures. Even a slight inflammatory reaction destroys the osteogenetic power of the periosteum and leaves to the marrow the burden of ossification. Hence this process is always slow and often fails entirely. Loss of periosteum is the usual cause of delayed union after operations on bone.

Especially common is the delayed union after a comminuted or compound fracture of both bones of the leg. The fibula unites speedily, and thus holds the fragments of the tibia at such a distance from each other that the bony callus is inadequate to bridge the gap. The same thing may occur in the forearm.

Finally there are certain fractures which do not unite, although apposition, immobilization, and all the other factors are apparently perfect. Such failures are not explained.

The morbid anatomy of delayed union depends on many factors. The bones are united either by a band of fibrous tissue or by a distinct joint. In the former case there may be but little change in the shape of the fragments. Their edges may be slightly rounded off; but except for this, they remain as they were at the time of the fracture, united simply by a fibrous band in which no ossification has taken place. Or, on the other hand, there may have been some attempt at ossification, manifesting itself in exuberant callus, or in partial ossification of the fibrous band. Or, finally, there may be a progressive rarefying ostitis rendering the fragments soft and pointed and gradually absorbing them, thus constantly enlarging the gap.

Where there is a distinct joint (nearthrosis) the bone ends enlarge and become eburnated—they are said even to become covered with cartilage—and lie in a cavity containing a pseudo-synovial fluid, and surrounded by a dense fibrous capsule.

The prognosis depends on the amount of abnormal mobility, the time which has elapsed since the receipt of injury, the general health of the patient, and the treatment he has already undergone for the purpose of remedying the defect. In general, the prognosis should be guarded; for while union may be obtained by persistent efforts in apparently desperate cases, and after the lapse of many months, all efforts may fail even though the defect be small and the condition of the patient excellent.

Faulty union, by which term a union with deformity that might have been avoided is understood, is rather a complication of the treatment than of the fracture itself. In certain cases, on account of the nature of the fracture or the condition of the individual, any union, with however much deformity, is a proud achievement rather than a failure. Indeed,

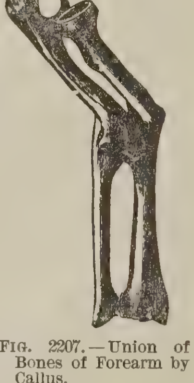

FIG. 2207.—Union of Bones of Forearm by Callus.

after no fracture is it possible to predict with certainty that every trace of the injury will disappear in time, while in many cases a greater or less amount of deformity will surely persist for all time. A common form of mal-union is union of the two bones of the forearm to each other (Fig. 2207), a condition which effectively limits pronation and supination.

Treatment.—The treatment of fractures in general will be considered according to the following scheme:

I. Prophylaxis.
II. Treatment of simple fractures.
General measures.
Reduction.
Immobilization, temporary and permanent.
Accessory measures.
The management of joints.
Massage.
Hot air.
Direct fixation.
III. Treatment of compound and gunshot fractures.
IV. Treatment of articular fractures.
V. Treatment of complications.
Early—
Gangrene.
Nerve injury.
Suppuration and sepsis.
Late—
Pain.
Joint stiffness.
Exuberant callus.
Delayed union.
Mal-union.

I. *Prophylaxis.*—The prophylaxis of fracture is more a matter of common sense than of surgery. No especial precautions need be suggested except to the surgeon. Fracture of the arm or leg of a fœtus during instrumental delivery is unfortunately not the most uncommon thing in the world, and the same may be said of fracture during operations on diseased bones. To avoid fracture in the latter class of cases it is not sufficient to leave a firm bridge of bone untouched. Besides that precaution the surgeon must be gentle in the use of heavy chisels and large forceps, lest the jar caused by the avulsion of a fragment be sufficient to split the entire shell.

II. *Treatment of Simple Fractures.—General Measures:* The first thought that arises after the diagnosis of fracture has been made concerns the *setting* of the broken bone. Yet many impediments may arise to make the setting or reduction of the fracture a matter of secondary importance. The patient's condition may be such as to demand immediate removal to home or hospital. It may be impossible to make a definite diagnosis or immediately to effect reduction on account of local swelling or spasm. In such cases transportation is the immediate question, and whether the fracture has been set or not, it is of the greatest importance that the injury already inflicted be not increased by the jolts and jars of travelling. To this end the fractured limb must either be confided to the care of an intelligent attendant who shall support it in his hands, or it must be bound firmly but not tightly to a board or a barrel stave, care being taken to immobilize the adjacent joints as well as the fragments themselves. And since the greatest danger is that the fragments may be driven through the skin and a simple fracture thus rendered compound, the dressing is to be applied with sufficient pressure near bulging fragments to secure safety in this regard. It is scarcely necessary to recommend gentleness and despatch in transportation as well as in the local manipulations.

If the patient is to remain long in bed, the quality of the bed demands consideration. If impending bed sores are foreseen, the patient will ultimately have to lie on a water bed, and he should be placed there from the beginning. If one of the long bones of the lower extremity is broken, a flat couch is necessary, such as can be produced by sliding several boards between the springs and the mattress of an ordinary bedstead. Fancy fracture beds are unessential.

The patient, once in bed with his fracture reduced and immobilized, as a rule has to pass long weeks of waiting before the member can be of use again, and it is the surgeon's part to attend during this season more to the general condition of the patient than to his fracture. The fight may be a life-and-death one, or it may be a mere question of when to get the patient about. But in any case, however insignificant, the surgeon who wishes to do full justice to his patient will not be satisfied with mere union of the broken bone, but will, by the aid of those measures grouped as "accessory," endeavor to leave his patient in the best possible condition at the time he throws off his splints and is "discharged cured."

Reduction: Many fractures cause no displacement and therefore require no reduction. Such are fractures of the ribs, pelvis, shaft of the fibula, etc. Many others are complicated by some impediment to reduction. Such an impediment may be temporary or permanent.

The local swelling caused by hemorrhage or œdema may, by obscuring the diagnosis and preventing immobilization, make it advisable to postpone reduction. Elevation of the limb and a temporary dressing applied as firmly as the patient permits will speedily reduce the swelling. Muscular spasm occasionally impedes reduction in the same way and may be overcome by similar measures or by the administration of chloroform or opium. The danger of gangrene may also discourage reduction during the first few days, although reduction often lessens this danger. In any such case reduction may usually be postponed for two or three days with perfect propriety and with no subsequent effect on union or function; but longer delay is inadvisable lest the bones acquire relations with the surrounding tissues so firm as to impede reduction.

Reduction is never literally impossible in a recent fracture, though it may well be inadvisable if the operation for the removal of the impediment to reduction involves too great a risk or puts the patient in a worse condition than before. Thus certain impacted fractures, notably fracture of the neck of the femur, are irreducible, since reduction, which could be accomplished only imperfectly and with great difficulty, would separate the ends of the bone, so that in place of a slightly deformed and shortened member a false joint would result, with considerable or complete loss of function. Another form of permanent obstruction occurs when reduction is mechanically impossible because of interposed soft parts, or fragments of bone, or interlocking of the bone ends. The associated contusion may make the diagnosis as doubtful as the treatment.

In face of such complications the surgeon may well hesitate. The choice lies between immediate operation and expectant treatment in the hope that the patient may yet have a fairly useful limb which may in any case be improved by a later operation. As a rule, immediate operation is to be preferred, and irreducible fractures involving a joint especially demand the knife, for if let alone they will almost inevitably heal with excessive callus, impaired function, and with little prospect of relief by secondary operation.

Elements which should weigh against operation are the unfamiliarity of the surgeon with such treatment, and the impossibility of obtaining asepsis. The best results will be obtained if operation is performed within twenty-four hours of the time of fracture. Later, the union is delayed by œdema and contusion. The operative method is described below.

Unless some of the above complications are present, the sooner the fracture is reduced the better. This is not only that union may progress favorably but also for the comfort of the patient; his pains are immediately lessened and the œdematous reaction is diminished.

The general principles upon which reduction is usually performed are:

1. To place the lower fragment in the same plane as the upper one, and
2. To draw it into place by relaxing the muscles as much as possible, and by traction and counter-traction.

These rules hold good because the upper fragment (the one nearest the body) is usually more or less fixed by the muscles attached to it, and the lower fragment must be manipulated with a knowledge of this position, obtained often rather from anatomy and pathology than from inspection and palpation of the broken limb.

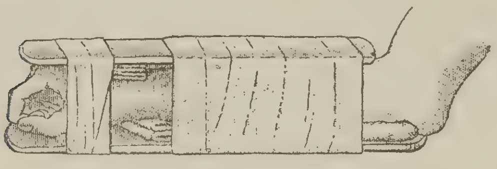

FIG. 2208.—Board Splints Applied.

Evidently no generalization is possible in this matter. Each fracture must be discussed individually. But few fractures are reduced directly by apposing the fragments, although local manipulations are often employed to aid traction as well as to ascertain its results.

The reduction of green-stick fractures is accomplished by forcibly bending the bone back until it is straightened. It may be necessary to break it entirely across before it will remain straight.

Small fragments, if they interfere with reduction or threaten to slough through the skin, should be removed with due antiseptic precautions.

If one of the fragments pierce a muscle, relaxation of the muscle by flexion or extension of the neighboring joints may aid materially in its extraction.

Immobilization: The apparatus employed to retain a fracture in place is called a splint. Before describing the different varieties of splints, temporary and permanent, a few rules governing their use may be laid down.

1. The splint must immobilize the broken bone. To do this it must usually immobilize the joints at each end of the bone.
2. It must not be allowed to interfere with the circulation, hence
3. Temporary splints to be used during the first few days after fracture, while the circulation of the limb is impaired, should never consist of a snug encasement.
4. Splints made of metal or board should be wide enough to prevent the circular retention dressing from encircling the limb snugly, and
5. The toes and fingers must always remain exposed as indices of the circulation in the extremity.
6. When a dressing is applied to the upper part of a limb, light compression by bandage should be carried to the toes or fingers to prevent œdema and pain.
7. Every patient wearing a splint should be inspected once a week, and the splint removed for that purpose, if necessary.

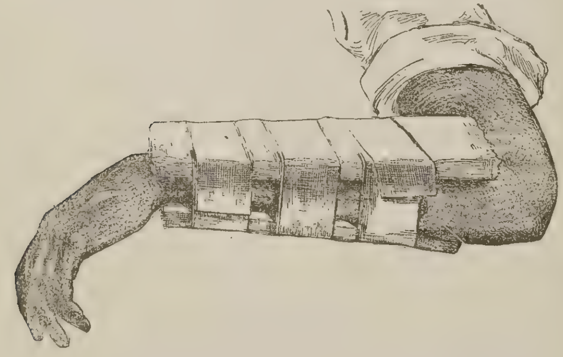

FIG. 2209.—Mode of Using Adhesive Plaster for Retaining Splints.

8. After the first two weeks (or even sooner) the splints should be so arranged as to allow the greatest possible freedom to adjoining joints as far as compatible with the union of the bone.

Once the fragments are in place they must be kept so. Yet in many instances during the first few days there is so much swelling about the seat of fracture that the retentive apparatus must be applied as much for pressure as for immobilization, and after the swelling has been thus reduced this primary dressing is no longer suitable. Other reasons for the use of a temporary dressing are transportation and the treatment of compound fractures. In many varieties of fracture the temporary apparatus may be entirely dispensed with, permanent dressings being applied at once.

Temporary Immobilization: The important requirements of a temporary splint are that it may be (1) everywhere obtainable, and (2) universally and readily applicable. Hence wide side splints of board, cardboard, or metal are usually employed for this purpose (Fig. 2208). Such articles are obtainable everywhere and may be bound to the limb with any cloth, though adhesive plaster makes the best binder (Fig. 2209). The board need only be wide enough to prevent the bandage from compressing the limb laterally and long enough to immobilize the adjacent joints. It should be roughly padded with cotton, heaped up to fill the space left by the natural depressions of the limb and thickened around the bony prominences (but not on them) so as to prevent pressure upon them.

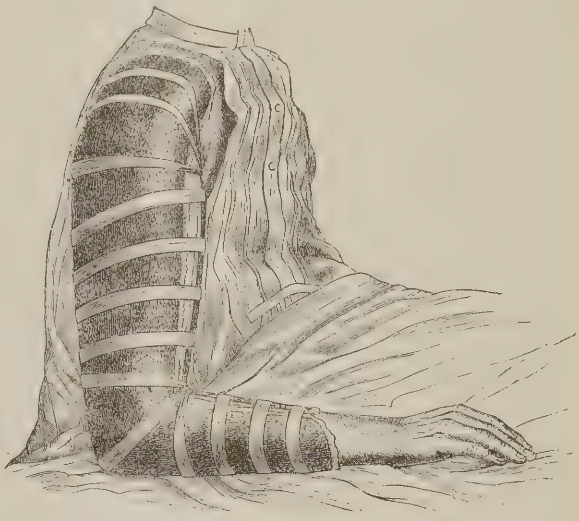

FIG. 2210.—Moulded Splint for Fracture of the Humerus.

When the material is at hand, *moulded splints* of gutta percha (Fig. 2210), leather, felt, or wire mesh make more elegant and lighter splints. But these have been discarded by most surgeons in favor of moulded splints of *plaster of Paris.* This substance is easily obtained and can readily be moulded into a splint which, for durability, stoutness, and lightness, leaves nothing to be desired. Unfortunately the plaster adheres firmly to the surgeon's hands, and although this may be prevented in some degree by anointing the hands with vaselin, and its removal assisted by glycerin and hot water, yet it is an annoyance that cannot be completely overcome.

To make a *plaster-of-Paris splint,* previously prepared bandages may be employed or the plaster may be applied to the bandage at the making of the splint. The former method is by far the simpler; but unless the bandages are hermetically sealed in tins they soon absorb enough moisture from the atmosphere to render them absolutely useless, and unfortunately their condition cannot always be determined until they are being applied.

If prepared bandages are to be used to make a moulded splint, they are immersed in hot water to which a little salt or zinc sulphate is added. The length of splint required is measured off with a muslin bandage, which is then laid upon a towel or oilcloth. By this time the plaster bandage will be soaked through, and may be taken from the water, squeezed gently and applied back and forth until the muslin bandage (which had best be a double thickness) is covered by six or eight lengths of plaster bandage. A little of the hot water sprinkled here and there adds smoothness, and the whole is strengthened and polished with a handful of dry plaster rubbed in and moistened. This band is then applied lengthwise to the limb with the muslin bandage next to the skin. A snug roller bandage binds it in place, and the limb being laid or propped in a suitable position, there results in about six hours a light, strong splint, perfectly moulded to the limb and removable at will.

If there are no prepared bandages at hand, the plaster is poured into an agate basin, enough hot water is added to bring it to the consistence of a rather thin paste, and it is then applied to the muslin bandage between the folds of a gauze bandage, a layer of plaster being spread quite thick between every two layers of bandage. Six or eight layers of the gauze bandage are used and the dressing is finished and applied as directed above. When using the prepared bandages the tendency is not to wet them enough; when using the fresh plaster to wet it too much. Hence the latter usually sets more slowly.

Such devices as waterproofing the exterior of a splint with varnish, protecting it with rubber tissue, or strengthening it with additional plaster at its angles or with iron bands or bass wood slivers, will suggest themselves to the surgeon. Such splints should last two or three weeks.

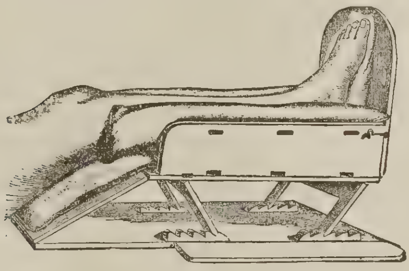

FIG. 2211.—Petit's Fracture Box.

For fractures of the leg or ankle the *fracture box* (Fig. 2211), or better the *Volkmann splint* (Fig. 2212) is often applied during the first few days. Unless care is taken to prevent it, the pressure of the heel upon the splint causes excruciating pain and later ulceration. To avoid this the foot is suspended by a strip of adhesive plaster passing from the ankle under the heel and along the sole of the foot and over the top of the foot-piece to which it is attached by a reversed strip. This splint, moreover, must be well padded, especially on each side of the tendo Achilis. If pain is felt in spite of these precautions it may be relieved by pushing the cotton from under the heel up on each side of the ankle. When using these appliances a snug bandage should be previously applied to the limb in order to hasten the subsidence of swelling.

Permanent Immobilization.—The various splints described in the preceding paragraph, except the moulded splints, are too clumsy and do not produce sufficient immobilization to be useful after the first œdematous reaction has subsided. As for the moulded splints, the more one uses them the more satisfactory they seem, especially for fractures about the upper arm and leg; but when the primary reaction subsides the primary splint no longer fits and must be exchanged for a tighter one.

For strictly permanent dressings, to be changed not oftener than every week or two, a complete *encasement* of the limb in *plaster of Paris* forms a very efficient splint (Fig. 2213). The limb is first encased in a thin layer of cotton or muslin bandage (or it may be simply greased thickly with vaselin) and held in proper position while the wetted (*v. s.*) plaster bandage is applied from below upward. In applying a plaster encasement the bandage is run as for a reverse, but the "reverse" is not made, the bandage being simply turned sharply downward. Two or three thicknesses of bandage and a liberal polish of plaster are ample allowance. The toes and fingers should always be left exposed. If plaster bandages cannot be obtained the freshly prepared plaster is applied between layers of gauze bandage, in a manner similar to that described above.

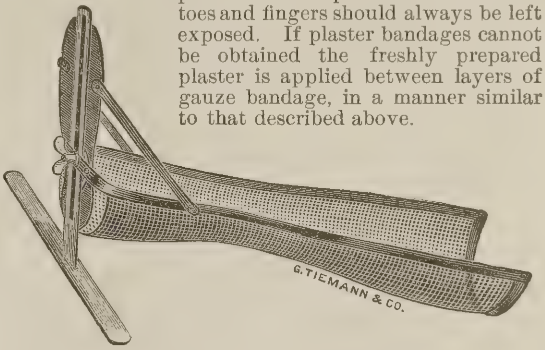
G. TIEMANN & CO.

FIG. 2212.—Volkmann's T Splint.

Silicate of soda ("liquid glass") may be employed in a similar manner. This substance makes a far more elegant and somewhat lighter splint, than the plaster of Paris, but it sets slowly and is neither so strong nor so enduring as the other

Various forms of *mechanical splints* are employed in certain cases. Except where traction is necessary in order to maintain reduction, mechanical devices are rarely necessary. A past and fanciful age was rich in such appliances which were more notable for their ingenuity of construction and general clumsiness than for any aptness to their special purposes. These have been swept away by the neatness and cleanliness of modern surgery; but the ever-increasing ingenuity of the orthopedist to relieve the pain and deformity of disease promises a revival of mechanical apparatus for the treatment of fracture (for those who can afford the luxury). As yet the only notable examples of mechanical splints are employed for fractures of the thigh and spine and will be considered under those headings.

Accessory Measures: The Management of Joints.—Since stiffness of the joints adjacent to a fractured bone is of such frequent occurrence as to be the universal complication of fracture, and since this more than any other thing is likely to retard convalescence, it is not far to conclude that the joints should be exercised at the earliest possible moment, and in the manner best calculated to procure satisfactory results.

Stimson lays down two rules on this point:

1. "So long as the joint is swollen and hot, so long as its use is followed by an increase of swelling and heat and by persistent pain, so long must it be kept at rest; and so long must active treatment be limited to massage or elastic compression; and, as a rule, this attitude of non-interference may be maintained until after union of the fracture has become complete. Then . . . passive motion or . . . gradually increasing use of the limb will rapidly restore the function of the joint.

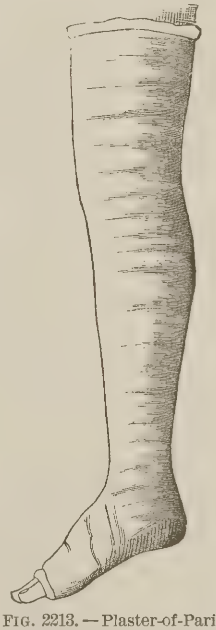

FIG. 2213.—Plaster-of-Paris Encasement for Fracture of the Leg.

2. "Forcible passive motion, with or without anæsthesia, is always harmful before the second month, and even after that time it is far more likely to do harm than good. . . . The proceeding should, I think, be almost wholly abandoned, and in its place we should resort to massage, constant use within existing limits, and possibly to the recently introduced method of prolonged exposure to high, dry temperatures; and these failing, I should prefer to expose the joint by incision in order to remove such intra-articular obstacles as might exist and be removable rather than blindly to seek to break and tear them without knowing what and where they are."

Since the fingers are peculiarly liable to stiffening, especially if kept extended, they should always be immobilized in the position of flexion, and passive or active motion should be begun on them within the first two weeks.

Massage.—Massage at the hands of any one but an expert should never be employed until after union has taken place. Lucas Championnière is the ardent advocate of massage and passive motion in the early days. When employed with the utmost gentleness and skill these measures eliminate joint stiffness and hasten the resorption of the primary exudate and perhaps the union of the bone. But the treatment is expensive and therefore beyond the reach of most patients. Moreover, the benefit derived from it is in many cases a negligible quantity, while any mishap or excess of zeal on the part of the operator is not unlikely to delay union rather than to hasten it. Hence this treatment should be reserved for those cases in which the primary reaction is unduly prolonged or the joints are threatened.

When employed, massage should be given daily and very gently. Elastic pressure by a light rubber bandage is often equally useful. It is usually better to apply the bandage only by day.

Hot Air.—Treatment of recent fractures by dry air at a temperature between 300° and 400° F. has been advocated. The indications for its use are the same as those for massage. I have tried it only twice and in both cases it failed, though massage subsequently succeeded.

Ambulatory Treatment.—The vogue of the so-called "ambulatory treatment" is already waning. The idea is an extension of Lucas Championnière's theory that exercise is good for fractures and rest bad. Hence, it was urged, all persons suffering from fracture should be up and about at the earliest possible moment, and this may be accomplished for persons with broken legs by so strengthening the splint that the limb may be used in walking, the weight of the body being transmitted by the splint instead of by the broken bones.

It is a matter of common experience that a Pott's fracture is sometimes no more disabling than a sprained ankle, and that after the permanent splint has been applied, it may be possible to force the patient to walk with the aid of crutches, so little inconvenience does the injured ankle cause him. In such cases ambulatory treatment is quite appropriate, but the application of this theory to fractures of the femur or the tibia and fibula is entirely unwarranted and extremely dangerous. If there is danger of faulty or delayed union from gentle massage at the hands of a competent operator, this danger is multiplied a hundredfold for a patient thus turned out to take care of himself. Moreover, the alleged advantages of rapid union and ability to work are not proven. The safest form of ambulatory splint is a hip splint such as is employed for tuberculous disease, with a plaster encasement for the fracture. For fracture of the leg a very heavy plaster encasement is sometimes employed in which two stout lateral rods of iron or wood are incorporated, bearing above upon a band of plaster under the tuberosities of the tibia and terminating below in a cross-piece two inches below the sole of the foot. This splint transmits the body weight from the tuberosities through the splint to the ground. Though clumsy it is safe for a Pott's fracture but dangerous for a fracture of the leg.

Ambulatory splints should never be applied until after the subsidence of the primary swelling.

Direct Fixation.—Like the other accessory measures, direct fixation has been paraded as the only treatment for fractures. Yet though incision and manual reposition of the displaced bones would give theoretically perfect results, and lessen the primary œdema by allowing evacuation of the clots, the eminently satisfactory results obtained by the ordinary treatment as well as the danger of infection leave but few supporters to this theory.

The accepted indications for direct fixation are:

1. When incision is necessary for reduction, to remove comminuted fragments, or in certain special fractures (patella) to maintain apposition.
2. For most compound fractures.
3. For delayed union after milder means have failed.

The methods of applying direct fixation are two:

1. Periosteal suture.
2. Fixation of the bones themselves.

Suture of the periosteum and adjacent soft tissues gives but an indirect support to the bone. It can prevent only separation of the ends. Angular deviation and overriding must be prevented by splints.

Fixation of the bone is commonly accomplished by silver wire, nails, bone pegs, or special clamps riveted about the bone. These methods effect admirable apposition, but they have a common defect, viz., the liability of these wires, pegs, or clamps to act as irritating foreign bodies, causing bone softening either immediately about them or extending through the whole width of the bone ends and resulting in a fibrous union. This unfortunate result attends a large proportion of cases treated in this manner.

If, therefore, direct fixation is employed, periosteal suture is to be preferred, and if this does not effect sufficiently firm apposition, the bones should be united by a removable suture of silver or silk or some such apparatus as the Parkhill clamp * to be detached at the end of ten days or as soon as the provisional callus has been thrown out.

III. *Compound and Gunshot Fractures.*—The treatment of compound fractures may be broadly classified thus:

1. Treatment of "primary" or "direct" compound fractures in which the wound is gaping, contused, and infected.
2. Treatment of "secondary" or "indirect" compound fractures in which the wound is small, clean, and negligible.

The basis for this distinction has been noted above.

1. The treatment of direct compound fractures comprises extensive incision, copious irrigation with mild solutions, the trimming away and removal of all contused and befouled tissue, and all loose chips that are not firmly attached to the periosteum.

The periosteum and fascia are loosely sutured and gauze or gutta-percha tissue drains are inserted down to the bone, and antiseptic dressings applied.

The splint should be applied to the limb before the patient leaves the operating table. If the wound is expected to run a clean course a fenestrated plaster encasement is the best, reinforced if necessary by iron bands. If, however, suppuration is feared and daily dressings are expected, such a splint soon becomes soiled and soaked with the discharge from the wound in spite of every precaution. Removable splints, such as moulded splints, Volkmann's splint, the double inclined plane (Fig. 2214),

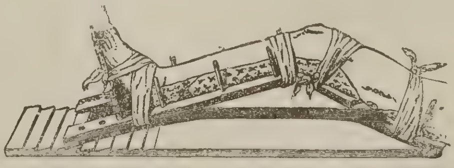

FIG. 2214.—Esmarch's Double-inclined Plane.

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* Annals of Surgery, 1898, xxvii., 553.

Hodgen's (Fig. 2221) or Smith's splints (Fig. 2215) are then to be preferred. The latter splints afford elevation as well as immobilization.

The treatment of the wound is of the greatest importance. While the primary irrigation and antisepsis are chiefly to be depended upon to prevent infection, the irritation as well as the danger of infection from frequent change of dressings is a common cause of late suppuration. If the wound is but loosely sutured and lightly packed in the first place, it may sometimes be left undisturbed until the fourth day. If at the first dressing the wound is clean it should be disturbed as little as possible. Some of the drainage may be removed. The wound should not be irrigated. After this the drainage is renewed at intervals of from forty-eight to seventy-two hours until the wound is healed. If active suppuration occurs it must be combated by the usual antiseptic methods.

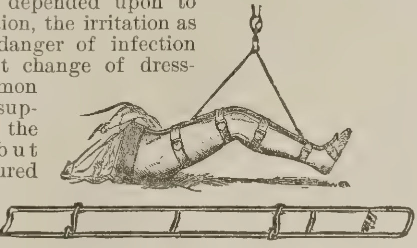


Fig. 2215.—Nathan R. Smith's Anterior Splint.

Amputation is rarely indicated at the time of accident. However crushed the limb may be, every attempt should be made to save it. If, however, the lower segment of the limb remains pulseless and incision into it produces only a stagnant venous ooze, it may be wiser to amputate rather than to subject the patient to a second operation. The rule in amputating is to save as much tissue as possible, and to this end it may even be wise, in case the surgeon feels confident of his asepsis, to allow the line of amputation to coincide in great part with that of the laceration.

2. When the wound is small and clean it may be treated by a superficial cleansing and precautionary drainage, or it may require operation as described above, at the surgeon's discretion.

Gunshot Fractures.—Fractures caused by bullets may be widely compounded or practically simple fractures. The special indications for treatment are dealt with elsewhere (see *Gunshot wounds*).

IV. *Articular Fractures.*—Most of the classical fractures involving joints, such as fractures of the anatomical neck of the humerus, fractures of the patella, Pott's fracture, etc., are to be treated by certain well-defined, special methods. But there are many unusual fractures involving joints, often caused by a direct crushing injury. They have few common features, and each must be dealt with individually. For the treatment of such fractures a few general rules may be laid down.

1. If the fracture is compounded, the joint should be fully cleansed of all foreign matter, fragments of bone, blood clots, etc., and copiously irrigated. Then, if there is a chance of avoiding infection, the joint should be sealed by suturing the soft tissues closely about it. If suppuration is anticipated continuous irrigation should be established and maintained for forty-eight hours. If suppuration appears in a case in which it had not been looked for, the joint must be opened and irrigated continuously until the infection is conquered.

2. Simple articular fractures usually require no special treatment except early passive motion to prevent ankylosis. Exceptionally operation may be undertaken to reconstruct a thoroughly disorganized joint, or to extract a fragment that defies reduction and threatens the future efficiency of the joint.

V. *Treatment of Complications.*—The early complications that require special treatment are (1) gangrene, (2) injury to a nerve, and (3) suppuration and sepsis. Among the later ones (1) persistent pain or paralysis, (2) joint stiffness, (3) delayed union, and (4) mal-union deserve mention.

Gangrene: Gangrene of the limb may often be averted by multiple longitudinal incisions through the skin and fascia (made under primary anæsthesia) followed by elevation and hot wet dressings. If these means fail (as they may do unexpectedly, since under an unbroken skin the deeper tissues may be reduced to a pulp by a crushing force) amputation should be resorted to at once. The line of amputation may be estimated by producing artificial ischæmia with the Esmarch bandage (to be used only if there is no infection). Whatever tissue reassumes a pink hue after the pressure is removed may be saved. If, however, the gangrene is progressive and septic, rapid amputation well above the gangrenous region should be performed immediately.

Injury to a Nerve: It should never be too hastily assumed that a nerve has been ruptured. The injury is a rare one, while traumatic paralysis, hysterical in nature or because the nerve has been bruised, is common and transitory. Moreover, no harm can come from waiting. Operation should therefore be delayed at least a week or two, at the end of which time, if there is no diminution of paralysis or anæsthesia, the rupture of a nerve may be considered probable and the nerve cut down upon and sutured. (See under Fractures of the Lower Extremity of the Humerus.)

Severe and persistent neuralgia may indicate pressure by a fragment or by the callus. To relieve it an incision is necessary, and if no such physical cause for the neuralgia is found, stretching the nerve may relieve the pain.

Suppuration and Sepsis: These complications are confined to compound fractures. To treat them judiciously may tax the keenest surgical instinct, for in many cases the suppuration is at first slight and the constitutional disturbance insignificant. To leave the wound unirrigated is to invite extension of the infection throughout the lacerated tissues, while to irrigate freely is to break down fibrinous adhesions, to bruise granulations, and to irritate the whole area to such an extent as enormously to encourage infection. To steer between the two is less a matter of intelligence than of instinct derived from experience. If the infection promises to be slight, and occurs later than the fourth or fifth day when healing has already progressed so far as to afford a barrier to the spread of suppuration, the pus may simply be mopped away and the cavity swabbed out with peroxide of hydrogen and packed with bichloride gauze (1 to 2,000) or one of the newer organic silver salts. If, however, the infection occurs early or presents other grave features, there is nothing for it but to irrigate the wound copiously (one to two quarts of bichloride solution 1 to 10,000) once and thereafter to change the dressings frequently in the hope that the infection may thus be repressed or at least confined to one spot.

The milder infections may be conquered by these local measures. The more virulent processes require wet dressings, antiseptic baths, multiple incisions, continuous irrigation or even amputations. As already stated, the union of the bone is delayed by the infection as well as by the manipulations, but I have known union to take place in the femur in two cases after a year of hospital treatment. Such a result could not be expected in an old man. He would not survive the prolonged suppuration.

Persistent Pain or Paralysis: There is always a good deal of stiffness and weakness for the first weeks after the patient gets about, but as long as his symptoms are lessening they require no treatment. Progress may be encouraged by any form of muscular or circulatory stimulation such as massage, exercise, passive motion, hot air, electricity, strychnine and other tonics. The salicylic-acid derivatives and colchicine may help.

Pains amounting in severity to an actual neuralgia and persistent paralysis are often best treated by operative investigation of the nerves.

Joint Stiffness: If this does not react to the treatment mentioned above, operation is the only resource.

Fingers that have remained immobile in the extended position for more than two months are practically beyond hope.

Delayed Union: This condition may be treated systemically by tonics, locally by irritants, or by operation. If the delayed union is due to systemic disease, such as syphilis, malaria, etc., this etiological condition must be combated. Over and above this it is customary to administer phosphorus or phosphate of lime. Thyroid extract has been recently employed. It has proved useful at the hands of some and has failed with others.

The local irritative measures may be employed in connection with the drugs or after they have failed. Painting with iodine or guaiacol and cauterization are of little benefit. Exercise is especially useful to encourage union of the tibia, when there is not too much separation. The leg is encased in plaster and the patient is instructed to walk upon it daily. Massage may help. If these measures fail congestion may be produced by bandaging the limb tightly above the fracture. The bandage is applied for two or three hours at a time, on alternate days, for a week. A more efficient and more painful treatment is the injection of a few drops of chloride of zinc (ten per cent.), tincture of iodine or alcohol into the band of union. This sets up an acute reaction which may be followed by ossification. Electrolysis is said to have the same effect. Still greater irritation may be produced by violently wrenching the limb about while the patient is anæsthetized.

Schaffer has obtained union in old fractures of the neck of the femur by special braces exerting direct pressure over the trochanter.

Operation is necessary when the above means fail, or when union is mechanically impossible on account of separation of the bone ends by the interposition of other tissues, or when they (tibia, ulna) are held apart by a parallel bone.

There are various methods of operating. The bone may be cut down upon, the band of union cut away, and the bone ends approximated by periosteal suture or bone pegs or wire. Parkhill's clamp seems especially fitted for this sort of work, and it has given good results after other methods have failed. Permanent wiring, pegging, or clamping is dangerous, for the reasons already stated (p. 256).

The presence of an actual new joint makes no material difference in the operative technique.

The prospect of success from any of these methods is none too glowing. The causes of failure of union may continue in force, and the difficulty in obtaining and maintaining the necessary approximation of the two fragments is great. All else failing amputation may be resorted to.

VII. *Mal-Union.*—When once a bone has united with deformity, the disfigurement can be remedied only by osteoclasis or osteotomy. Before suggesting such treatment, however, the surgeon will do well to consider whether with the material at hand, viz., the existing bony tissue, he can obtain a material improvement from any operation.

Fractures of the lower extremity of the humerus and Pott's fracture often call for relief, in the one case to overcome the restricted mobility of the elbow joint, in the other to remedy the deformity. In either case the best plan of treatment is to chisel through the bones along the old lines of fracture, to remove superfluous callus and then to reduce and splint the fracture as though it were a fresh one. This is done in the foot through curved internal and external incisions. In the elbow it may be impossible to ascertain the nature of the fracture or to be sure of what is callus and what is fragment. If such be the case the surgeon should rest satisfied with the removal of such bony protuberances as interfere with motion and the breaking up of adhesions. Passive motion should be begun at the end of a week and practised daily in order to prevent recurrence of the ankylosis.

SPECIAL FRACTURES.

Fractures of the Skull—See *Head, Injuries of.*

Fractures of the Spine—See *Spine, Surgery of the.*

Fractures of the Bones of the Face—See *Jaws, Injuries of;* and *Nose, Injuries of.*

Fractures of the Laryngeal Cartilages—See *Larynx, Fractures and Dislocations of.*

Fractures of the Clavicle.—Excepting the bones of the forearm and leg, the clavicle is broken more often than any bone in the body.

For clinical purposes the bone is divided arbitrarily into three equal portions. To the inner third are attached the strong ligaments binding the clavicle to the sternum and the first rib; the outer third is protected by the trapezius and the deltoid muscles and the coraco-clavicular ligament; the middle third is unprotected and it suffers by far the greatest number of fractures.

Varieties.—But five compound fractures of the clavicle are recorded. Multiple and comminuted fractures are rare. I have obtained an excellent result by removing a small fragment.

Incomplete fractures are insisted upon by Hamilton and Platt. The former reports 34 incomplete fractures in a series of 157 cases; the latter 25 in 115. The injury is unimportant. It is caused by a fall upon the shoulder in a young person. Within a few days after the fall a swelling appears about the middle third of the bone. False motion and crepitus may sometimes be elicited. No treatment is necessary, except perhaps a broad sling to elevate the elbow.

Simple fracture of the middle third may be transverse (children) or oblique (adults); the shoulder, losing its support, sinks downward and inward. The inner fragment lies above or in front of the outer. When the line of fracture is transverse there may be angular displacement or none at all.

Fracture of the outer third is rare. It is usually caused by direct violence. There may be no displacement and the fracture may pass unrecognized (Lane). Displacement when present is usually angular. If the fracture is within the outer inch of the bone the apex of the angle is upward, otherwise it is usually backward. Fracture of the inner third is very rare. Displacement is slight or absent.

Fracture of both clavicles is unusual. It has been known to cause considerable dyspnœa on account of the weight of the upper extremities upon the chest.

Etiology.—While fracture of the clavicle is usually caused by a fall upon the shoulder or the outstretched arm, it may be due to direct violence or even to such muscular efforts as striking a blow or lifting a heavy weight.

Symptoms and Course.—In fracture of the middle third crepitus cannot always be obtained, but the drooping shoulder and the shortening and deformity of the bone as compared with its fellow are characteristic. Flexion and extension of the arm may be but little impaired, yet abduction is quite impossible.

Fractures of the inner and outer thirds and all incomplete fractures can be diagnosed only by palpation along the bone.

The course of the injury is usually simple, though such complications as puncture of the subclavian vein, aneurism from injury to the artery, rupture of the brachial plexus, and emphysema from puncture of the lung, have been reported. Union may be expected at the end of the fourth week. As a rule, some displacement and shortening persist.

Treatment.—The method of reduction and immobilization is the same for all the varieties, except certain fractures of the outer third which require direct pressure by means of a strip of adhesive plaster passed over the point of fracture and the point of the elbow and back over the fracture (Stimson's dressing for dislocation of the outer end of the clavicle), and a simple sling. In all other cases the object aimed at is to remove the weight of the upper extremity, which drags the outer fragment downward, forward, and inward. To effect reduction, the simplest method is to lay the patient upon his back, manipulating the shoulder until the bone resumes its normal direction. This is simple: but to retain the bone in place is a far more difficult matter; witness the infinite number of methods employed.

The treatment employed depends upon the result desired, whether a useful limb merely or a beautiful neck. To attain the former result a simple sling often suffices, while the latter may perhaps not be reached by the surgeon's most ingenious devices. In general, if a perfect result is desired, the patient must be kept on *her* back for three weeks in the most suitable of the dressings to be described below.

The dressings usually employed are Mayor's scarf, Velpeau's bandage, Sayre's dressing, and Moore's bandage. In applying these several thicknesses of towel or non-absorbent cotton (carded lamb's wool is better) should be padded into the axilla and between the limb and the side.

Mayor's scarf is made of a square of stuff, the diagonal of which is long enough to reach around the body. It is applied like an ordinary sling, but the lower ends are passed around the body and knotted in the back. This is a very satisfactory appliance for dispensary practice.

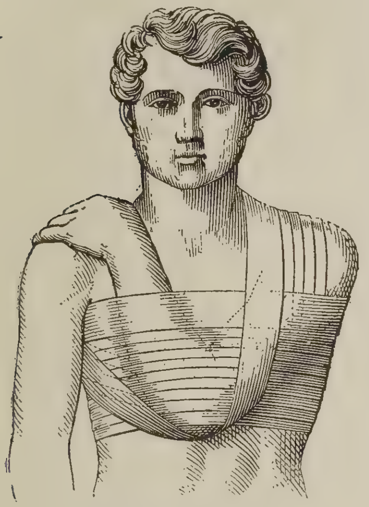


FIG. 2216.—Velpeau's Bandage.

Velpeau's bandage (Fig. 2216) is applied with the hand of the injured side placed on the opposite shoulder, "and the limb is drawn snugly up toward the neck by successive turns of the roller, which, beginning at the opposite axilla, pass obliquely across the back, over the shoulder, in front of the arm, under the elbow, and back to the axilla; after three or four such turns have been placed the bandage is carried circularly around the body, covering in the arm from below upward. The turns should be secured by stitching or by soaking in plaster."

Sayre's Dressing (Figs. 2217 and 2218) consists of "two strips of adhesive plaster, each about three inches wide, and long enough to go once and a half around the body; one end of the first strap is stitched loosely about the arm just below the axilla, and the other end carried around the back and the opposite side to the chest in front. The second strap is then carried from the top of the shoulder on the uninjured side across the back, under the elbow, and along the forearm to the shoulder again. The elbow should be drawn back while the first strap is applied, and well forward while the second is."

Of the latter two dressings Sayre's is the more efficient and lasting but the less comfortable. In each the hand should be left exposed.

Moore's bandage is made of a wide muslin bandage or scarf about two yards long. "Its centre is placed under the olecranon, the forearm being flexed at a right angle, the end that is next the body is carried up between the arm and the side, in front of and over the shoulder across the back and under the opposite axilla, the other end is carried around the outer side and front of the elbow, then between it and the side to the back and across the back to the opposite shoulder, where it is made fast to the first end. The elbow is drawn backward and pressed upward." The wrist is supported by a sling.

Various other splints are employed, too numerous to mention.

FRACTURES OF THE SCAPULA.—Fractures of the scapula are classified as: (1) fractures of the body; (2) of the inferior angle; (3) of the upper angle and supraspinous fossa; (4) of the spine; (5) of the acromion; (6) of the coracoid process; (7) through the surgical neck; (8) of the glenoid cavity.

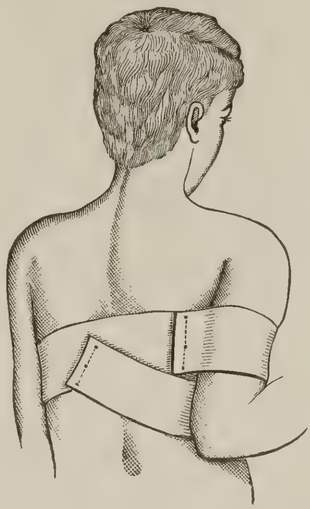


FIG. 2217.—Sayre's Dressing for Fractured Clavicle. First strap.

Fractures of the Body, Lower Angle and Upper Angle.—These fractures are caused by direct violence or muscular action. The lower angle may be displaced forward and upward. Otherwise the displacement is insignificant. There are localized tenderness and swelling, and false motion and crepitus may perhaps be obtained. Fracture of either angle is extremely rare.

The arm may be put in a sling and the scapula immobilized by broad bands of adhesive plaster encircling the chest.

The Spine of the Scapula is fractured by direct violence. False motion and crepitus may be elicited. The arm should be kept in a sling.

Fracture of the Acromion is usually caused by a fall on the shoulder. Either the whole process or merely its tip is broken off. Epiphyseal separation is not uncommon. The contusion often obscures the signs of fracture during the first days, but later the displacement outward and downward may be felt. If the whole process is broken off the shoulder droops. Crepitus may sometimes be obtained by elevation or abduction of the arm. Spontaneous motions of the arm, especially abduction, are restricted. Bony union is not to be expected.

The treatment is that of fracture of the outer third of the clavicle.

Fracture of the Coracoid Process is a pathological curiosity. It usually occurs in connection with dislocation of the shoulder or other fractures. The symptoms are obscure, the diagnosis is difficult, reduction impossible, and the prognosis good.

Fractures of the Neck of the Scapula (including all those that separate the glenoid cavity from the body of the bone) are caused in the same way as dislocation of the shoulder, which they resemble closely. The glenoid process slips downward with the humerus and the long head of the triceps attached. The displacement is limited by the spino-glenoid and coraco-clavicular ligaments and the tension of the soft parts over the shoulder.

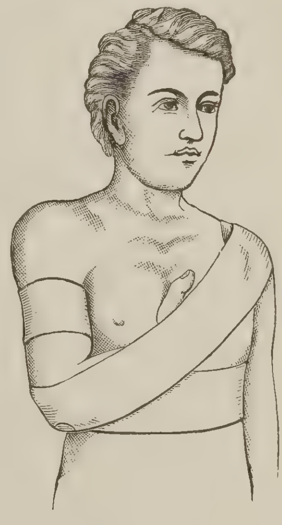


FIG. 2218.—Sayre's Dressing. First and second straps.

The symptoms are those of dislocation of the shoulder, from which the fracture is differentiated by the fact that elevation of the arm produces crepitus and obliterates the deformity, which recurs as soon as the pressure is removed. The treatment is by Stimson's dressing for dislocation of the outer end of the clavicle (*q. v.*). Bony union with some displacement may be expected.

The Rim of the Glenoid Cavity is sometimes broken by dislocation of the shoulder.

FRACTURES OF THE HUMERUS.—Fractures of the humerus are classified as fractures of the upper extremity, fractures of the shaft, and fractures of the lower extremity.

Fractures of the Upper Extremity.—This title includes fissures of the head of the bone, a condition with no clinical significance, and avulsion of the greater or lesser tuberosity, usually a complication of dislocation, recognized by localized tenderness and crepitus, and treated by immobilization (after reducing the dislocation) in outward or inward rotation, according to the tuberosity involved. More important fractures are (1) fracture of the anatomical neck, (2) fracture of the surgical neck, (3) separation of the epiphysis, and (4) fracture dislocation.

True Fracture of the Anatomical Neck is extremely uncommon. The line of fracture usually runs along the anatomical neck and partly through one or both tuberosities. Unless a tuberosity is separated from the shaft, or the head dislocated, the diagnosis is usually impossible, and when a tuberosity is separated the fracture is often a high one of the surgical neck. Strict accuracy of diagnosis, however, may be aided by the *x*-rays in the future. The subjective symptoms vary from slight pain to complete disability. The periosteum is usually in greater part untorn and the displacement slight, though it may simulate dislocation. Crepitus may usually be obtained and the tuberosity may not partake in rotation imparted to the shaft of the bone. Exuberant callus with ossification of the capsule of the joint may result, or there may be non-union.

The treatment is simple immobilization with traction if there is a tendency to shortening. If suppuration should complicate failure of union, incision, removal of the fragment, and free drainage would be necessary.

Fracture of the Surgical Neck is the commonest fracture of the upper end of the humerus. This includes all fractures below the epiphyseal line. The lesion is usually caused by a fall on the shoulder or elbow causing a compression or torsion. Hence the line of fracture is irregular and comminution is not rare. There may be impaction. The upper fragment is usually flexed, abducted, and rotated outward, the lower one slightly displaced inward.

Function is completely lost; there is much local swelling and the elbow is usually abducted simulating dislocation; but the head is in place, and there is local tenderness along the line of fracture and tenderness when the elbow is pressed upward. Unless there is impaction rotation of the arm is not communicated to the trochanter.

If displacement and shortening are present reduction may be accomplished by traction in the line of the upper fragment, namely, abduction and slight flexion. The best retention dressing is a plaster band running along the inner side of the arm from axilla to elbow and with two tails at each end encircling the shoulder and forearm (Hennequin's splint), or an external moulded splint as for fracture of the shaft (Fig. 2210). The elbow is flexed and left unsupported. A narrow band slings the wrist. If displacement or shortening recurs it is overcome by splinting the arm in abduction over a triangular pad reaching from elbow to axilla, made by cracking a piece of cardboard, holding the two sides at an angle of some 30° to 40°, filling in with soft cloths or cotton, and sewing a cover over all. The pad is placed with its sharp angle in the axilla, its base at the elbow (*conf.* Scudder, "Fractures"). Counter-traction is obtained by suspending a five-pound weight at the elbow. If the patient is confined to his bed the weight is attached as for fractures of the thigh (*q. v.*). The tendency to displacement is overcome at the end of two weeks and union is firm at the end of five or six weeks.

Separation of the Epiphysis.—This lesion replaces high fractures of the surgical neck in the young. The epiphyseal line runs through the lower edge of the tuberosities and the epiphysis is hollowed out in its centre, capping the shaft, as it were. The periosteum is usually little torn, the shaft displaced forward and its posterior edge fitted into the cup of the epiphysis which is tilted back. The upper edge of the shaft can, therefore, usually be felt below and in front of the acromion. The head is in place. Function is lost. Upward pressure on the elbow is painful. There is tenderness at the point of fracture.

Reduction is accomplished by abduction and direct pressure upon the ends of the fragments. The subsequent treatment is that of fracture of the surgical neck. Union is prompt, yet premature ossification of the cartilage may lead to shortening of the arm. Surgery is called for if the untorn periosteum prevents reduction, or later if union has taken place with deformity and the range of motion is much impeded.

Fracture-Dislocation.—Dislocation of the head of the humerus is sometimes complicated by fracture of the anatomical or surgical neck of the bone (see *Dislocations*). The proper treatment is to endeavor to replace the bone by traction and manipulations with the patient anæsthetized and prepared for operation. If this fails the head of the bone should be cut down upon and replaced with the aid of McBurney's hook, or removed if replacement is impossible. The older methods of awaiting union before reduction or trying to obtain a false joint have proved eminently unsatisfactory.

Fractures of the Shaft.—Every variety of fracture of a long bone is met with in the humerus. Muscular effort not infrequently causes the fracture. The most notable complications are injury to the brachial vessels and the musculo-spiral nerve.

Reduction is effected by traction. Very high fractures may have to be treated as fractures of the surgical neck, low fractures as supracondylar fractures, contused or compound fractures by rest in bed with the arm supported on cushions until all danger of inflammatory complications has passed. The dressing I prefer is a moulded plaster-of-Paris splint from the side of the neck over the shoulder, down the outer and posterior aspect of the arm, under the elbow and forearm to just above the wrist or a similar gutta-percha splint (Fig. 2210). When this is applied the elbow must be padded an inch deep in cotton. On the second or third day the splint is removed, the greater part of the cotton extracted, and the splint replaced and held in place by adhesive plaster, over the shoulder, around the arm just above and below the point of fracture (thus leaving it open for inspection), on the arm and forearm close to the elbow, and lower down the forearm. The dressing is completed by a shoulder spica and a sling about the wrist, and an axillary triangle if necessary (see above). With the limb in this splint there should be enough traction to prevent overlapping or angular deformity. This traction is allowed by the removal of the cotton from under the elbow and maintained by the adhesive strips on the upper forearm. The patient should be seen twice a week for the first three weeks, and if at any time deformity has recurred it must be promptly overcome by suspending a five-pound weight from the elbow, by coaptation splints of basswood, or by renewing the splint with a greater allowance for elbow traction. The sling at the wrist must not support the splint lest it elevate the elbow. Union is firm at the end of six weeks.

Fractures of the Lower End.—These may be classified as supracondylar fracture, fracture of the internal epicondyle (there are only two recorded cases of fracture of the external epicondyle), fracture of the internal condyle, of the external condyle, intercondylar fractures, hypocondylar fractures, and epiphyseal separation. This confusing array is much simplified by a few general considerations of diagnosis and treatment.

Diagnosis.—To differentiate sprain, dislocation, and fracture about the elbow is a matter of physical examination. Evidence of abnormality in the bones themselves indicates fracture. Evidence of abnormality in the relation of the bones to one another indicates dislocation. Entire absence of these abnormalities indicates simple sprain.

Evidence of abnormality in the relation of the bones to one another is obtained by locating the tips of the two epicondyles, the olecranon, and the head of the radius. When the elbow is fully extended the three former should be in the same horizontal plane, and the head of the radius be recognized as a projection just below the external condyle. It is identified by the motion imparted to it by rotation of the forearm. If the relations of olecranon and radius with the epicondyles are not the same as in the normal elbow of the opposite side (with which comparison should always be made) there is dislocation, which may often be verified by an estimation of the abnormal axes of the bones.

Evidence of abnormality in the bone (*i.e.*, the humerus) is obtained in several ways: by eliciting false motion or crepitus between the condyles and the shaft or small fragments; by mapping out the general deformity of the arm as well as the local deformities about the elbow, the displacement of one or both condyles, and the irregularities along the supracondylar ridges; and finally by eliciting pain. If there is transverse fracture there will be pain on pressing the flexed elbow upward. A local point of pain can often be identified along one or both supracondyloid ridges where the fracture nears the surface, and if there is a line of fracture between the condyles, pressing the two condyles toward each other is painful.

Dislocation and fracture often coexist.

Thus the examination is begun by inspection to note any manifest deformity. An effort is then made to locate and determine the relations of the bony points mentioned above, and the range of motion, active and passive, tested with an eye to abnormal mobility, especially lateral mobility, and crepitus. The supracondylar ridges are searched for points of irregularity and tenderness, and pressure is made under the elbow and upon the two condyles to elicit tenderness. Suspected parts of the joint are then reviewed for false motion or crepitus.

The contusion is, however, often so excessive as to frustrate the surgeon's best efforts. Even an examination under ether may fail to elucidate the diagnosis. The x rays may then be appealed to. The evidence which they furnish should be definite.

Treatment.—Once the diagnosis is established reduction is not difficult. Rarely the fragment is so rotated as to make reduction impossible. Such fragments must be cut down upon and replaced or excised. Fragments of the epicondyles cannot often be retained in place. Their displacement is unimportant, however. Larger fragments acting rebelliously may be excised or sutured in place or nailed to the adjoining bone by a spike driven through the soft tissues and protruding through the dressings, to be removed within ten days.

With these exceptions reduction and retention are easily managed. The best position for the forearm is in all cases one of semiflexion with the natural pronation. The apparent security of complete flexion or extension does not compensate for the displacement which so often occurs with the elbow in these positions. For compound fractures, however, vertical suspension with the elbow extended is a convenient position during the first days, after which the limb may be brought down to the usual semiflexion.

The most convenient splint is a posterior moulded plaster band or wire gutter running the whole length of the arm and forearm and bent to a right angle at the elbow. If adhesive straps are used to retain the splint they should not cover the fragment (the position of which must be frequently verified). A five-pound weight hung from the elbow will overcome the tendency to displacement. The elbow is never to be supported. A sling about the wrist is sufficient.

If perfect reduction is not maintained, a cubitus varus or valgus may result which can be remedied only by osteotomy.

When union is firm and the arm is freed from its splint (at the end of five weeks) the elbow will be found sore and stiff. Motion and massage will help loosen up the joint, but an excessive zeal will only succeed in encouraging the growth of exuberant callus and so permanently restricting the range of motion. Such exuberant callus may also occur through no fault of the surgeon, but it is difficult to estimate its importance within six months. At the end of that time the joint will have gained its maximum of freedom, and the remaining restrictions caused by displaced fragments, ossified ligaments, callus projecting into the olecranon or coronoid fossæ or elsewhere into the joint can be removed only by the chisel. Yet it is well to be conservative in such operations. A mobility of from forty to fifty degrees at the elbow is about all that is needed as far as utility is concerned, and unless there is some definite projection of bone or callus the removal of which will clearly liberate the joint, an operation may well result in nothing more than disabling the patient for a few weeks, during which time new callus replaces that which was excised and after which the patient returns to his duties no better off than before. No general rules for operation can therefore be laid down. Each case must be decided on its own merits.

Of the numerous vessels and nerves in close relation to the joint, the ulnar nerve is the only one likely to be injured. Ulnar paralysis and anæsthesia have been known to disappear spontaneously as late as three months after injury, but in doubtful cases an early operation should do no harm and might do much good.

In *supracondylar fracture*, the lower fragment consists of both condyles and the whole lower extremity of the humerus. The line of fracture is oblique and the fragment slips upward and backward or upward and forward. The condition usually resembles a dislocation, but the relation of olecranon to condyle is unchanged and lateral mobility can be obtained with crepitus. Moreover the fracture when reduced has often a tendency to slip out of place again, with crepitus.

Fracture of an epicondyle is recognized by the abnormal mobility, displacement, and crepitation. Persistent displacement is unimportant since the line of fracture is entirely outside the joint.

In *fracture of the internal condyle* the line of fracture runs obliquely downward and outward from some point in the epicondylar ridge to the region between the trochlea and capitellum. The fragment with the ulna attached is usually displaced backward and the radius may be dislocated in the same direction. Abnormal adduction and antero-posterior sliding are possible. The ulnar nerve may be injured. There is a marked tendency to recurrence of the displacement with the production of cubitus varus. This may be overcome by immobilization with extension, with special care to preserve the normal outward angle at the elbow, by immobilization in flexion aided by a weight supported from the elbow, or by operative fixation.

Fracture of the external condyle is somewhat more frequent than the last mentioned. Its features are similar to those of fracture of the internal condyle, *mutatis mutandis*, but there is less liability to displacement. Indeed there may be a tendency to displacement downward, which would only be encouraged by suspending a weight from the elbow.

Intercondyloid fractures are caused by direct violence. The fracture is often compound or comminuted, its general lines being T- or Y-shaped, with the condyles separated from the shaft and from each other. The ulna may be jammed between the fragments. Reduction is important and may be difficult on account of the number and displacements of fragments. If reduction cannot be performed thoroughly under an anæsthetic, the bones had best be cut down upon and fastened in place or excised according to the judgment of the surgeon.

Separation of the epiphysis is rare. (Consult Plate XXVIII., Fig. 6.) The condition simulates backward dislocation, but the epicondyles retain their relation to the olecranon and the whole may be reduced (and recurs) with cartilaginous crepitus. The usual treatment is required.

Hypocondylar fractures, i.e., fractures of the articular processes, either one or both together, are extremely rare. They are caused by a severe crushing force applied beneath the elbow or transmitted up the forearm. When not associated with other injuries about the joint, they are to be recognized only by crepitus, the *x*-rays, or the displacement of a fragment to a place where it can be left.

Fractures of the Bones of the Forearm.—It is convenient to group the fractures of both bones of the forearm under three headings: fracture of the upper ends, fracture of the shafts, and fracture of the lower ends.

Fractures of the upper ends include fractures of the olecranon, of the coronoid, and of the head of the radius.

Fracture of the Olecranon (see Plate XXVIII., Fig. 8), though usually due to a fall on the elbow, is apparently caused by the violent contraction of the triceps (Stimson). The position and direction of the line of fracture vary widely. The displacement may be so slight that the chief evidences of fracture are independent mobility and crepitus, or so great that the gap between the olecranon and the shaft is readily felt. Yet practically the displacement is found to be slight in most cases. The tendency of the triceps tendon to carry the fragment upward is counterbalanced by the strain on the lateral fibrous attachments of that tendon.

Hence in a surprisingly large proportion of cases immobilization of the elbow in a position of slight flexion is quite compatible with good position of the fragments. The best splint is an anterior moulded one since it allows inspection of the fragment. Careful watching is necessary to forestall late displacement by the continued action of the triceps. To prevent displacement early or late it may be necessary to keep the elbow fully extended, to draw down the fragment by means of adhesive plaster strips, by Malgaigne's hooks, or by operation as for fracture of the patella, the suture being passed from side to side through the tendon and the ulna. If ankylosis, a rare complication, is feared, on account of the intensity of the inflammatory reaction, early passive motion (third week) may be employed. This treatment should, however, be conducted with extreme gentleness since it has been known to cause refracture.

Union is usually fibrous, sometimes bony, and may fail entirely. Unless motion is interfered with by adhesions within the joint, a satisfactory power of extension may be anticipated even though the separation of the fragments amounts to half an inch.

For non-union or undue separation of the fragments the bone may be cut down upon, the fibrous tissues excised, and the fragments sutured together.

Fracture of the Coronoid Process is usually a complication of backward dislocation of the elbow. It is rarely recognized and is unimportant. The separation is slight, for the fragment is held in place by the tendon of the brachialis anticus attached about and below it. This fracture may allow recurrence of the associated dislocation. The elbow must be immobilized in flexion for three weeks.

Fracture of the Head of the Radius is recognized by the localized tenderness, the discovery of a displaced fragment, pain in abduction of the forearm, and pain and crepitus on rotation. The absence of pain on adduction or on pressure of the two bones toward each other excludes fracture of the neck of the bone. The treatment is immobilization, removal of displaced fragments, or, if these fail, resection of the head of the bone.

Fractures of the Shaft of One or Both Bones.—These fractures are usually caused by direct violence. Green-stick fractures are commoner here than anywhere else in the body. Platt records 199 fractures of the shaft. Of these 122 were complete; 66 affected both bones; 42 the radius alone, and 14 the ulna alone. Of the 77 green-stick fractures, in 63 both bones were broken, the radius alone in 9, the ulna alone in 5. Instead of both bones breaking, the ulna alone may give way while the head of the radius is dislocated. When both bones are fractured the radial fracture is commonly nearer the elbow than the ulnar one. The usual displacements depend on the actions of the pronator and supinator muscles. The former tend to draw the fragments toward each other, and this is especially marked in short lower fragments acted upon solely by the pronator quadratus; the latter put the upper fragment of the radius (especially if the break is above the insertion of the pronator teres in the middle third of the bone) in supination (Plate XXVIII. Fig. 1). Overlapping also usually exists.

It is scarcely possible to mistake a fracture of both bones. When the ulna is broken the seat of fracture may be located by palpation. This is impossible along the radius, which lies surrounded by muscles for the greater part of its length; but when the radius is fractured forced pronation cannot be resisted and independent mobility and crepitus may be obtained by grasping the head of the bone firmly while the hand is gently rotated.

Reduction is of prime importance. It is accomplished by local manipulation and traction, direct when both bones are broken, toward the sound bone if only one has given way. It is especially important that the bones be crowded apart lest they unite to each other and thus effectually prevent rotation (Plate XXVIII. Fig. 7). This is accomplished by crowding the muscles between them and by the subsequent splinting. In the immobilization two important facts are to be borne in mind:

1. No circular dressing, bandage, nor splint may be applied close about the forearm. Such a dressing will force the fragments toward each other, or, worse still, it may cause gangrene or "ischæmic contracture" of the muscles of the forearm from which they may never recover.

2. Whenever the radius is broken, unless in its lower third, it is safe to immobilize the forearm in supination. The routine attitude of semipronation usually leaves some rotary displacement between the radial fragments (as explained above) which, while it may not be enough to interfere materially with the function of the limb, still prevents complete supination. Moreover, the shafts of the bones are most widely separated in the position of supination and hence least likely to unite to each other.

The routine practice, therefore, of employing heavy wooden anterior and posterior splints (Figs. 2208, 2209) is most commendable. The splints run from the elbow to the knuckles. They are well padded and bound to the limb with strips of adhesive plaster, the boards being wide enough to prevent constriction. A small roller bandage elevates the palm of the hand from the anterior splint and the whole is encased in a roller bandage and supported by a sling with the hand supinated. A broad sling is employed reaching from elbow to hand. If the hand is not supinated care must be taken lest the sling, by supporting one end of the limb more than the other, cause an angular displacement or an approximation of the bones to each other.

If the limb is extensively contused or becomes markedly œdematous, it should be treated for a few days by elevation, hot wet dressings, and perhaps multiple incisions to prevent gangrene. This precaution may not be lightly disregarded since the muscles of the forearm may be reduced to a pulp, although the skin shows scarcely a sign of injury.

Fractures of the Lower Ends.—Platt tabulates 88 simple Colles' fractures, 7 with additional fracture of the lower end of the ulna, and but 2 fractures of the ulna only. Besides these he reports 6 cases of epiphyseal separation of both bones, 36 of the radius only, and 1 of the ulna alone. All of these varieties are clinically reducible to Colles' fracture. One other variety there is of fracture in this region, the so-called Barton and reversed Barton fractures. This condition is a splintering of the posterior or anterior edges of the under surface of the lower end of the radius by partial dislocation of the wrist backward or forward. The fracture is an insignificant complication of the dislocation and is rare.

Colles' Fracture.—"Every dislocation of the wrist is a Colles' fracture." As a statement this is false, but as

EXPLANATION OF PLATE XXVIII.

EXPLANATION OF PLATE XXVIII.

Fig. 1.—Fracture of the shaft of the radius above the insertion of the pronator teres, showing outward rotation of the upper fragment by the biceps and suggesting the necessity of splinting the forearm in full supination.

Fig. 2.—Longitudinal section of lower end of radius, showing old unreduced Colles' fracture.

Fig. 3.—Similar specimen, showing less displacement but more impaction.

Fig. 4.—Lateral displacement in Colles' fracture. Projection of the ulnar styloid process.

Fig. 5.—Diagrammatic representation of the bone lesion in Fig. 4.

Fig. 6.—Coronal section through the elbow joint, showing epiphyseal development of the capitellum, the internal epicondyle, and the head of the radius.

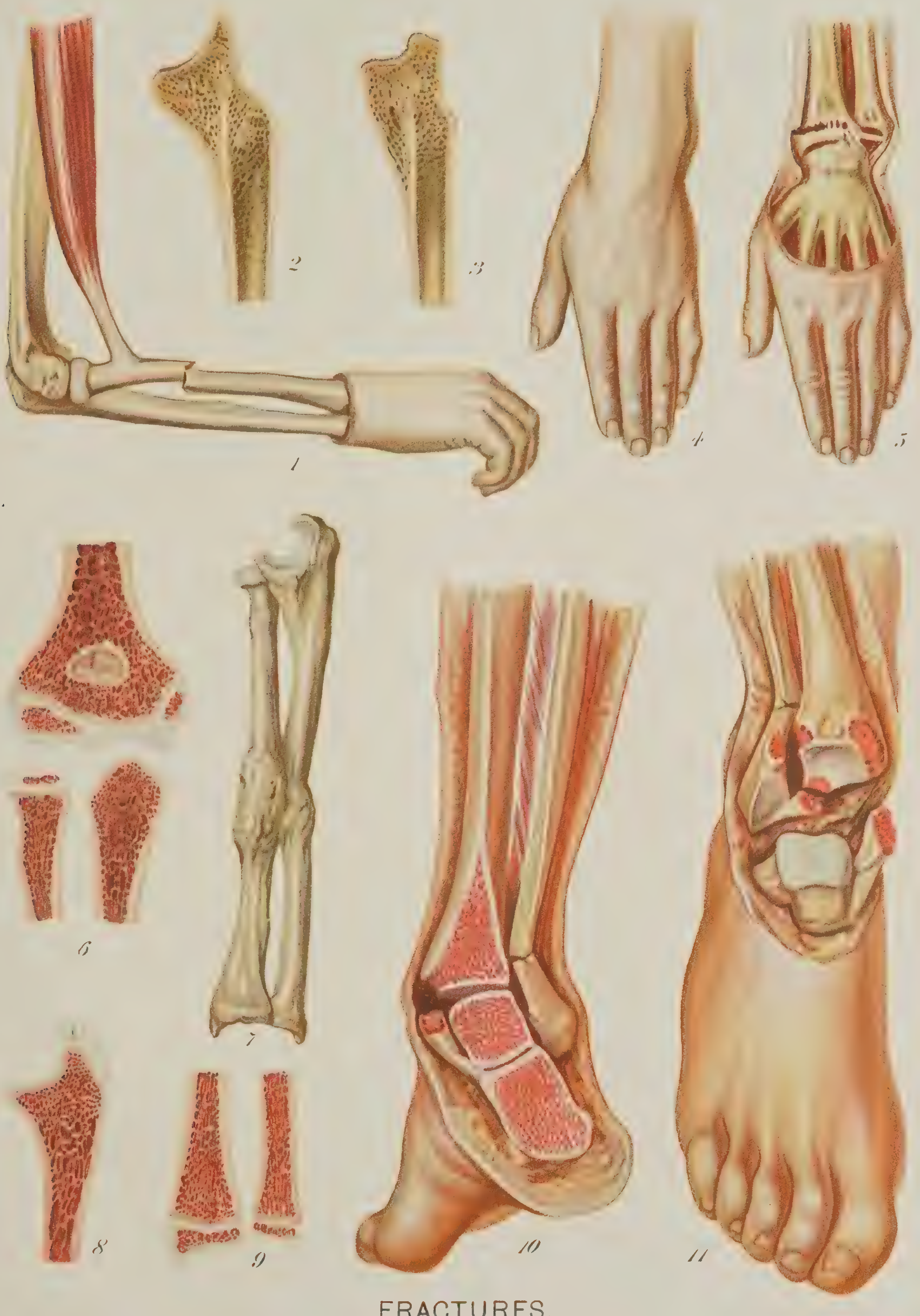
Fig. 7.—Old fracture of both bones of the forearm. The bones are united by exuberant callus.

Fig. 8.—Sagittal section of the ulna of a child, showing the epiphyseal cartilage in which the bony nucleus of the olecranon appears during the tenth year.

Fig. 9.—Coronal section, showing the epiphyses at the lower ends of the bones of the forearm.

Fig. 10.—Oblique section, showing tibial and fibular fractures and outward displacement in Pott's fracture.

Fig. 11.—Ankle joint laid open after Pott's fracture, showing points of fracture and tibio-fibular diastasis.



FRACTURES.

IMPORTANT ANATOMICAL AND PATHOLOGICAL FEATURES.—*(From Helferich's Atlas of Fractures and Dislocations.)*

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a point of view it will save the surgeon from many an error. No fracture of any single bone is so frequent. The cause of the fracture is usually a fall upon the palm of the hand. The lower end of the radius is broken more or less directly across within three-fourths of an inch of its articular surface. In the young the line of fracture often runs through the epiphyseal cartilage (Fig. 2219). The lower fragment may be displaced backward, but is commonly only tilted in that direction (Plate XXVIII. Fig. 9). It is comminuted as a rule and firmly impacted against the upper fragment. The styloid process or lower end of the ulna is rarely broken simultaneously.* The lateral ligaments of the joint are sometimes torn. The periosteum is stripped up from the posterior surface of the radius and the excessive callus produced under it in old unreduced cases produces the excessive protuberance seen in pathological specimens (Plate XXVIII., Figs. 2 and 3).

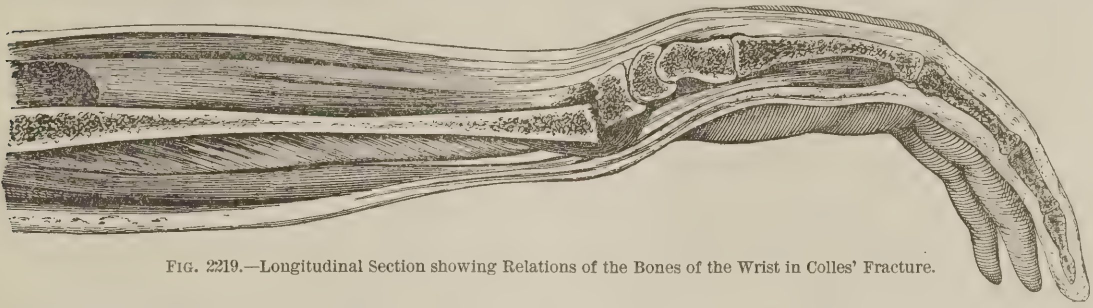

FIG. 2219.—Longitudinal Section showing Relations of the Bones of the Wrist in Colles' Fracture.

The bones of the carpus are carried backward by the tilting of the lower fragment, thus causing the characteristic "silver-fork" deformity, a projection of the back of the wrist with a corresponding depression anteriorly, very aptly compared to the curve of a fork (Fig. 2220). The hand is usually somewhat abducted through the shortening of its radial attachments (Plate XXVIII., Figs. 4 and 5). A more reliable sign of Colles' fracture and one which is never obscured (the above-mentioned deformity is often obscured by excessive swelling) is the elevation of the styloid process of the radius as compared with that of the opposite side. The styloid process of the radius, instead of being a quarter of an inch or so below the tip of the ulnar styloid, has risen to the same level or above it. The ulnar styloid is usually prominent (Plate XXVIII., Fig. 4). There is a line of tenderness over the back of the radius. Crepitus and abnormal mobility cannot commonly be elicited until after the fracture has been reduced.

The treatment of Colles' fracture is simple. Reduction is all important. It is accomplished by grasping the hand firmly as though to "shake hands." At the same time the surgeon grasps the patient's forearm just above the wrist, placing his thumb over the displaced fragment. The patient's hand is then drawn gently backward until he complains of pain. Immediately it is forced sharply backward before he has time to resist and then drawn downward and sharply flexed while the fragment is simultaneously pushed downward by the thumb upon it. These motions performed rapidly and forcibly will usually dislodge the fragment, a result announced by the diminution of the deformity and the appearance of abnormal mobility (and crepitus) where before the mobility was restricted. This method failing, the forearm may be placed on a table, the hand rapidly forced to and fro while the wrist is held firmly at the edge of the table and the fragment is pressed upon. Primary anæsthesia may be employed in rebellious cases.

The fracture once reduced is easily held in place. The usual dressing is a thin padded board along the back of the forearm to the knuckles and another along the anterior surface as for fractures of the shaft (Fig. 2208). This may be reinforced by a cuff made of several turns of adhesive plaster about the wrist. The fingers are liberated at the end of a week,* and all splints except the adhesive plaster cuff removed within three weeks. An anterior or posterior moulded plaster splint is a convenient dressing after the first week.

If this method of treatment is followed the bad results will be minimized. Shortening on the radial side is bound to persist in some cases of epiphyseolysis and in others in which the compression of the bone has been such as materially to reduce the size of the fragments. As a result of this, the ulnar styloid remains unduly prominent. In the middle-aged, rheumatic complications may be looked for. The best way to avert them is to employ daily massage from the start and passive motion as soon as possible. Yet the most intelligent treatment often fails in this regard; though it is almost impossible to persuade the patient that the surgeon's efforts are not to blame for the long months of suffering following so slight a fracture.

Reversed Colles' fracture is extremely rare. The impaction and displacement are directed toward the palmar instead of toward the dorsal surface.

Fractures of the Carpus.—In compound fractures the fragments are to be reduced or removed. Simple fractures are most unusual and a diagnosis can scarcely be made without the help of x-rays.

Metacarpal Fractures.—The displacement is usually angular backward, and slight. The fracture is readily recognized. The fist may be bound over a roller bandage for three weeks and after that a simple dorsal pad and spica employed. Beck's splint I have found serviceable. It is made of short pieces of rubber tubing pressed into the spaces between the metacarpal bones and held in place by two adhesive plaster straps, one just above the knuckles, the other near the mist. The hand is then bound over a roller bandage.

"Bennet's fracture" is the splitting off of a small fragment from the palmar surface of the base of the first metacarpal bone. The backward displacement of the remainder of the bone simulates subluxation. The thumb cannot be apposed to the index finger. It is to be immobilized in full abduction. Similar fractures occur in the other metacarpal bones; they are discovered by pressure upon the end of the bone eliciting tenderness at the point of fracture.

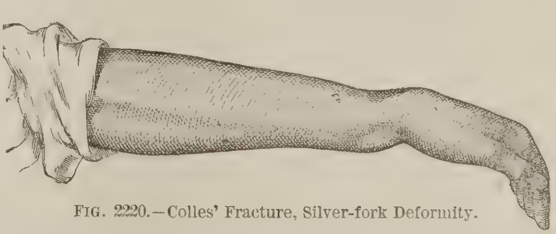

FIG. 2220.—Colles' Fracture, Silver-fork Deformity.

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* Fluoroscopy shows that the ulnar styloid is broken more often than is usually considered to be the case. Dr. E. A. Codman claims that the ulnar styloid is broken in at least sixty-two per cent. of cases.

* It is essential to liberate the fingers at the earliest possible moment, for they are very quick to become stiffened, especially if immobilized in extension, and slow to regain their full range of motion.

Phalangeal Fractures are often compound. Simple fractures may be immobilized by basswood splints or a plaster encasement, preferably in a position of flexion. After the first two weeks several thicknesses of adhesive plaster suffice. Compound fractures are, however, specially liable to suppuration and necrosis and the prolonged splinting usually results in one or more stiff joints. In such cases, therefore, it is often well to amputate in the first place.

FRACTURES OF THE FEMUR.—Indentations of the head of the femur by impact with the rim of the acetabulum during dislocations have no clinical significance.

Fractures of the Neck of the Femur.—These fractures occur at all ages by direct violence or by a fall upon the knee or foot, but they are specially common in old age when they may result from the slightest muscular action, such as the effort to avoid a fall or even a mere sudden turn. In fact so marked is this liability in the aged that every injury to the hip of an old person should be considered a fracture until this diagnosis has been disproved. This frequency of fracture in old age is due rather to the senile rarefaction of the bones than to the increased obliquity of the angle between neck and shaft.

Pathology: These fractures are classified as fractures through the narrow part of the neck (fracture through the neck, intracapsular fractures, fractura subcapitalis) and fracture at the base of the neck (extracapsular fracture, fractura intertrochanterica). In the former class the bone is broken close to the head. The vitality of the fragment may be completely lost, but more frequently it is maintained by the vessels in some untorn fragment of the periosteum (the vascular importance of the ligamentum teres is doubtful). In the latter class, the chief line of fracture follows the intertrochanteric lines. There is usually considerable comminution. The great trochanter may be split and the cancellous tissue of the neck is more or less crushed. These fractures, though usually spoken of as extracapsular, are often as much within the capsule as outside of it. They are also said to be impacted, but this impaction consists of a crushing of the neck of the bone which is wedged among the fragments about the trochanters, while true impaction in the sense of fixation is not common. The impaction occurs chiefly in the posterior part of the neck (exceptionally the reverse is true), and consequently the head rotates downward and backward as though hinged upon its anterior border. Hence the shortening and eversion of the thigh.

Symptoms and Diagnosis: The subjective symptoms are usually quite characteristic. There is almost entire loss of function. The patient can bear no weight on the limb, and when lying can move it but slowly and cannot lift the foot from the bed. The limb lies everted, abducted, and slightly flexed. Sometimes the eversion is so slight that it can be determined only as a resistance to inversion. This eversion is not entirely due to the fracture, for it is the position commonly noted in simple contusions. About the hip there is more or less swelling, ecchymosis, and pain. There may be an especially tender spot in front of the trochanter over the point of fracture. As a rule, the pain is elicited only by motion.

Exceptionally the limb is inverted and very rarely the patient can move it with a fair amount of freedom and even walk upon it.

The chief objective sign of fracture is shortening. This symptom is practically constant, although it may not be marked until some days have elapsed. The method of determining the shortening has already been described (p. 250), as well as the minute precautions to be observed in measuring the limbs at the same angle of flexion and abduction. The possibility of a congenital difference in the length of the two limbs is the only thing that renders this test fallacious. If, however, the limb can be proven to be distinctly shorter on the second or third day than it was immediately after the receipt of injury, the evidence is conclusive.

Shortening is also measured by Nelaton's line or Bryant's method (which estimate the elevation of the trochanter), or by measurement from the anterior superior spine of the ilium to the internal malleolus. Nelaton's line is drawn from the anterior superior spine to the tip of the ischial tuberosity on the same side. It should cross the tip of the trochanter when the limb is uninjured and slightly abducted. Bryant measures the distance of the tips of the trochanter from a perpendicular dropped from the anterior superior spine to the plane on which the patient lies. The estimation in either case is made by comparison with the opposite limb. Shortening may be inferred when the fascia above the trochanter is more depressible than on the sound side.

A relative fulness and tenderness in Scarpa's triangle is another fairly constant sign of fracture of the neck. If the trochanter is split, its increased antero-posterior diameter may perhaps be made out. The determination of a shorter radius of rotation in the trochanter is in the last degree impracticable.

Crepitus should never be sought for, though it may be elicited incidentally.

Diagnosis: The differentiation of fractures through the small part of the neck of the femur from those at the base is rarely practicable and never important. The chief differential point is comminution of the trochanter which so often accompanies fractures at the base of the femoral neck.

When the femur is broken below the neck there is a local spot of pain and deformity, the depressibility of Scarpa's triangle is unaffected, the trochanter is not elevated (though the limb is shortened) and does not partake of rotation imparted to the limb. When the head of the femur is dislocated it is readily felt if the dislocation is forward; and the limb is inverted, when it is dislocated backward. Those rare instances of inward rotation with fracture are usually mistaken for dislocation until the anæsthetic is administered for reduction when the position of the head is made out.

As to the positive diagnosis of fracture of the neck of the femur, it is based upon the signs and symptoms already enumerated. Doubtful cases, especially in the aged, must always be treated as fracture until the lapse of time has proven them mere contusions. The prognosis is good as regards life, though the shock of such a severe injury upon an aged person may prove fatal, through pneumonia, uræmia, fat embolism, or even simple "shock." Stimson says: "I have come to regard the third week as the time when the condition is most likely to change for the worse; that passed, cases usually do well."

On account of the impaction union is obtained with shortening and some loss of abduction and rotation. When the patient is aged the stiffness, pain, and weakness may never entirely wear away, even though union be perfect.

Firm union may be expected except in the aged. Yet even in the unsatisfactory cases, the fibrous union, the interlocking of the fragments, or surrounding tissues (it is usually impossible to tell which) hold the bone well enough in place for the limb to be used with the aid of a cane or stick. Such results follow fracture of the narrow part of the neck far more often than fracture at the base. The possibility of obtaining union several months after the injury by direct pressure over the trochanter (Schaffer) should not be lost sight of.

Treatment: If the patient is aged and infirm he must be put to bed and every care taken for his comfort and nutrition while but little attention is paid to the limb, which is slung in a Hodgen's splint, with as much traction as the patient will bear.

In younger subjects there is no danger to life, and the limb demands more care. Reduction must not be attempted. The patient is kept in bed and some form of traction apparatus is applied. The choice lies between Hodgen's splint and Buck's extension apparatus. The former is the more comfortable, the latter capable of exerting a greater pull.

For a Hodgen's splint (Fig. 2221) a piece of adhesive plaster three inches wide and long enough to reach from the upper part of the thigh, loosely around the foot and back to a corresponding point on the opposite side of the thigh, is selected. The middle two-fourths of this strip is folded twice upon itself (making a triple thickness), and nicked so as to allow the remainder to lie unfolded. A perforation is made at the centre of the strip and against it is fitted a stout perforated piece of wood two inches wide by five inches long (Fig. 2222). A strong cord knotted at one end is passed through the two perforations. A flannel bandage is then applied to the leg and foot, and the ends of the adhesive strip attached over one-half of the inner and outer aspects of the thigh, the middle folded portion lying below and about two inches away from the sole of the foot. Another bandage over the thigh and knee strengthens the grip of the plaster. The frame of the splint, upholstered with compresses pinned tightly from side to side, is then slid under the limb, and the metal half hoop (*O*) fitted over the ends to prevent them from collapsing. The cords (*DE* and *D′ E′*) are attached as shown in the figure and caught by a rope (*C*) which is attached to a crane at the foot of the bed. The cord of the adhesive plaster is then made fast at *F* bringing the piece of wood close against the bottom piece of the frame. The compresses are tightened and loosened to fit the inequalities of the limb. The end (*C*) is drawn tight enough to elevate the limb from the bed, its line of traction being at an angle of 50° to 70° with the horizon.

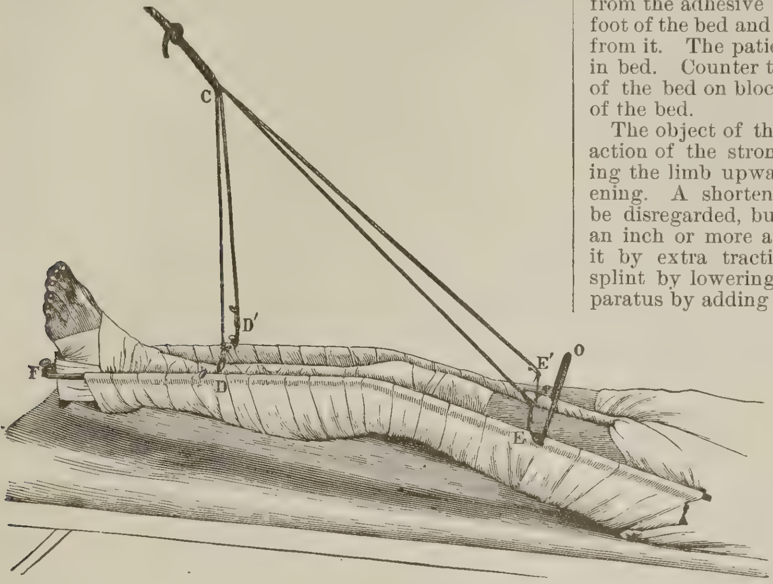

FIG. 2221.—Hodgen's Splint. (From Stimson's work of "Fractures," Lea Bros. & Co.)

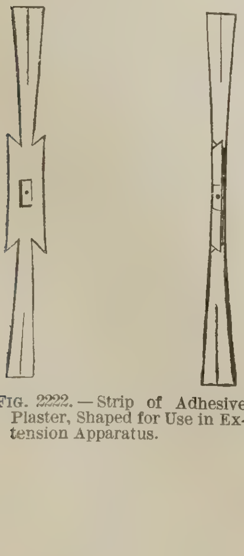

FIG. 2222.—Strip of Adhesive Plaster, Shaped for Use in Extension Apparatus.

For Buck's apparatus (Fig. 2223) the adhesive plaster and bandages are applied in the same manner, the outer bandage being made to include the footpiece of a Volkmann's sliding foot rest (Fig. 2224), which rests upon a frame in the bed, thus giving more play to the foot, and holding it upright. The cord from the adhesive plaster is then let over a pulley at the foot of the bed and a five- or ten-pound weight suspended from it. The patient must not be allowed to slide down in bed. Counter traction is made by elevating the foot of the bed on blocks or by tying the patient to the head of the bed.

The object of these traction splints is to overcome the action of the strong muscles which are constantly pulling the limb upward and tending to increase the shortening. A shortening of one-quarter of an inch may be disregarded, but if the shortening amounts to half an inch or more an effort should be made to overcome it by extra traction. This is done in the Hodgen's splint by lowering the line of traction, in Buck's apparatus by adding more weights.

Old and feeble patients should be gotten up in a chair within three weeks. Others may be in bed for the full six weeks, or may get up at the end of four weeks and walk about in a traction hip splint of the kind used for hip disease. Pressure made by a band over the trochanter may be beneficial at this stage.

Operative fixation and plaster encasement have been tried and rejected. The so-called ambulatory treatment has but a fictitious value. Those who can use it (the vigorous) do not need it. Those who would benefit by it (the aged) are too feeble and tottering to use it.

Fractures through the trochanter are treated like the above. *Fractures of the greater and lesser trochanters* are extremely rare.

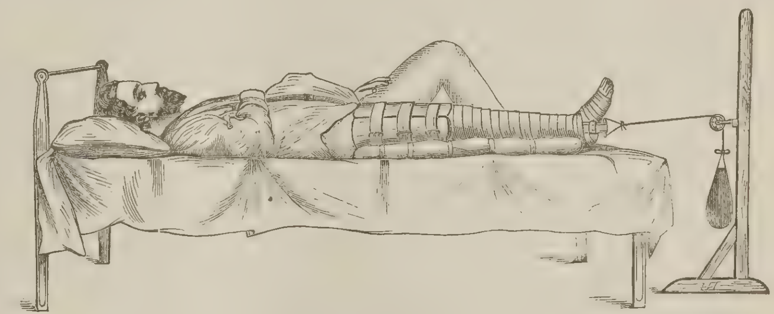

FIG. 2223.—Buck's Extension Apparatus.

Fractures of the Shaft.—These are usually caused by direct violence. The line of fracture may be extremely oblique and comminution is common. There may be considerable displacement. The lower fragment rides up behind or to the inner side of the upper one, producing both shortening and deformity. Subsequently outward rotation of either fragment will occur if the trochanter or the foot is not properly supported. Injury to vessels and nerves is rare. An annoying complication is the projection of the pointed end of the upper fragment, when the fracture occurs in the lower third of the shaft, into or even through the quadriceps extensor muscles. An acute serous synovitis of the knee is not uncommon.

The shortening is determined by measurement from the anterior superior spine of the ilium to the internal malleolus. The differential diagnosis between fracture of the shaft and fracture of the neck of the femur has been noted above. Abnormal motility and crepitus may be elicited by gentle manipulation. The less the limb is disturbed the better.

The *prognosis* is grave. According to Martin's recent statistics of one hundred cases, as a rule children do well. They are usually completely sound five months after injury and the shortening should be less than a half inch. With adults, however, it is different. The disability usually lasts eight months, and an ultimate shortening of an inch and a half may result even if the most skilful treatment is employed. This is in part due to an increased shortening after the patient leaves the hospital. Finally, Martin claims that "not more than one man in five who has sustained a simple fracture of the thigh will ever again be able-bodied."

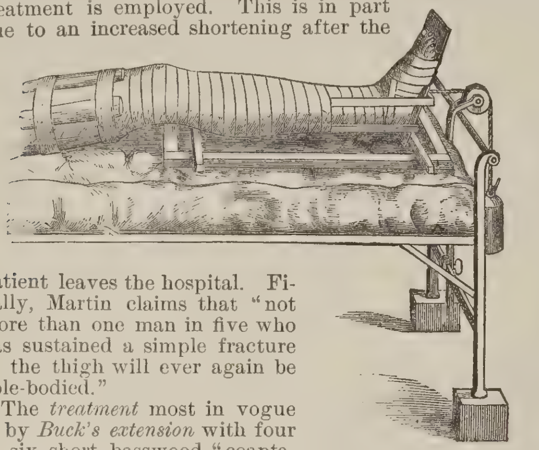

FIG. 2224.—Volkmann's Sliding-rest.

The *treatment* most in vogue is by *Buck's extension* with four to six short basswood "coaptation" splints (Fig. 2225) bound to the limb with adhesive plaster. Outward rotation of the upper fragment is prevented by a small hard pillow under the trochanter, while the lower one is held up by the *Volkmann sliding foot rest.* A weight is used sufficient to prevent shortening.

Hodgen's splint seems preferable for very high or low fractures, in the former case for the purpose of allowing slight flexion of the hip, and slight outward rotation of the foot to neutralize the unavoidable outward rotation of the short upper fragment; in the latter case to allow slight flexion of the knee without which good apposition cannot be maintained.

Compound fractures may be treated by the double inclined plane or an anterior suspended splint, or Hodgen's splint.

For infants the best treatment is vertical suspension of both limbs by adhesive plaster, etc., as for Buck's apparatus, in such a manner that the hips rest but lightly on the bed. The position is not uncomfortable, the child can be kept clean, and satisfactory immobilization can be maintained. *Children* do well under Buck's extension with a long side splint added (Fig. 2226) running from the chest to the ankle of the broken limb. A common oversight is the omission of a thick pad between the femur and the splint. When the broken limb is bandaged to the splint without such a pad it is bowed outward to such an extent as to produce from half an inch to an inch of shortening.

Plaster-of-Paris encasement is not reliable in the first weeks. Some of the above-mentioned traction splints must be kept on for five or six weeks, after which the patient may go about on crutches for three weeks longer with the limb in a plaster jacket or an orthopædic splint. A perfect limb without shortening is very rarely obtained.

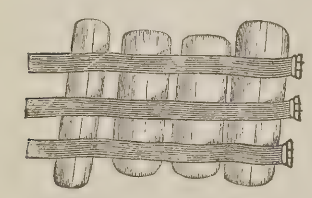

FIG. 2225.—Coaptation Splints used in the Treatment of Fracture of the Thigh by Buck's Extension.

Difficulty of reduction when a muscle is pierced by one of the fragments is met by traction with knee and hip flexed, or, if this fail, by the knife.

Fractures of the Lower End.—The fractures that occur in the lower end of the femur are separation of the epiphysis, intercondylar fracture, and separation of a single condyle. The last is very uncommon.

These fractures are caused by severe local violence or torsion or hyperextension of the knee. The common complications that render the injury serious are hæmarthrosis, going on to suppuration, compound fracture with the likelihood of a similar result, and laceration of the popliteal vessels and nerves.

The fracture may be obscured by effusion into the knee joint, but the diagnosis is readily reached by inspection and palpation.

If only one condyle is fractured the knee must be immobilized in extension, preferably on a posterior moulded splint. When there is intercondylar fracture or epiphyseolysis, the knee must be immobilized in partial flexion over a Hodgen's splint or a double inclined plane. The former apparatus is the more comfortable. Very little traction is needed.

The complications must be treated vigorously. When the knee joint is laid open by a compound fracture it should be treated by continuous irrigation with decinormal salt solution for at least twenty-four hours. The popliteal vessels may be so lacerated as to require amputation lest gangrene set in. A hæmatoma of the knee joint is best treated by elastic pressure, and if this prove useless, by evacuation of the blood clots through a small incision. This should never be undertaken without the most minute antiseptic precautions, for infection of the joint from this or any other cause threatens at least a stiff joint, at most amputation or death.

FRACTURE OF THE PATELLA.—Fracture of the patella occurs commonly in young adult males. It is caused by the muscular action of the quadriceps extensor, in stumbling, jumping, etc. The line of fracture is generally transverse and near the middle of the bone, though it may be but an avulsion of either tip. Less frequently the bone is broken by direct violence.

A sharp pain in the knee and an immediate complete loss of function call attention to the injury. If the joint is examined immediately the upper fragment is found drawn upward a half inch or so by the quadriceps, leaving a manifest gap between the fragments. The joint rapidly fills with blood and this adds to the displacement, which is, however, limited by the lateral attachments of the quadriceps tendon. If the displacement is not remedied, the slow contraction of the muscle, and in a less degree that of the ligamentum patellæ, draw the fragments farther and farther apart until they are separated by several inches. There may be fibrous union even in such a case, yet in spite of this the power of extension is very greatly impaired or lost entirely. Lateral and rotary displacement are unusual, but may occur as late results of contraction in the tissues.

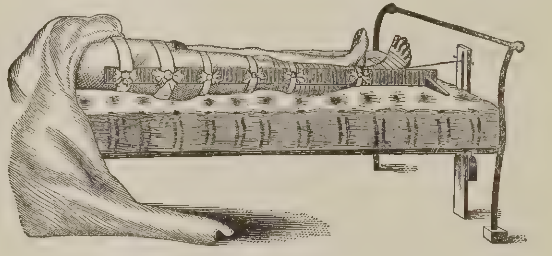

FIG. 2226.—Long Side Splint, with Traction.

The only accessory lesions are the transverse tears in each side of the capsule. The periosteum in front of the bone is torn irregularly so that its fringes drop between the fragments. Compound fracture is very rare.

The symptoms are pain and loss of extension. The diagnosis is made by palpating the broken bone and appreciating the gap between the fragments.

The *treatment* of this fracture by the usual mechanical methods has necessitated so prolonged a convalescence and exposed the patient to such unfortunate results (refracture, permanent stiffening, and loss of the power of extension) that operative measures have been welcomed by many surgeons of large experience. It does not appear, however, that operative success lessens the liability to refracture, and although it shortens convalescence materially, insures a full power of extension, and minimizes the prospect of stiffening, yet operative failure, which is infection, exposes the patient to the loss of limb or life, or at least to an absolutely stiff joint. For the knee joint succumbs to infection more readily than, or at least as readily as, any other region in the body. It is far more susceptible than the peritoneum, and the infection once begun rapidly involves the whole joint and imperils life.

While it is impracticable to detail here the operative successes and failures, or to substantiate an opinion upon which sound surgical judgments are still so much at variance, a moderate series of conclusions may be set down.

1. In the absence of a wide surgical experience and all the aseptic surroundings, assistants and implements, the general practitioner or the occasional surgeon must accept mechanical treatment with all its inconvenience.

2. The surgeon who feels himself sufficiently well equipped to venture operation should bear in mind the highest rule of asepsis, "Be sure your hands are thoroughly clean, and act as though they were absolutely dirty," which is to say, "Keep them from all contact with the wound." Rubber gloves should be permitted to lend no false sense of security.

3. Such compromising measures as the subcutaneous suture, or the use of Malgaigne's hooks, may well be more risky than a clean surgical wound made with no false sense of security, while they do not afford the three chief advantages of an open operation, viz.: the removal of all impediments to union, the evacuation of clots from the joint, and accurate apposition of the fragments.

Mechanical treatment is usually applied somewhat as follows: the limb is immobilized on a posterior moulded splint passing from the toes to the gluteal fold and maintaining the foot at a right angle and the knee extended (if a board splint is used the foot must not be allowed to droop). Hiding the fragments in a plaster encasement is a risky procedure. The limb is firmly bound to this with a roller bandage, after which the fragments are approximated as well as may be by direct pressure and held in place by several strips of adhesive plaster, encircling the limb and splint obliquely. Over all a light (Martin) rubber bandage is applied to hasten the absorption of the blood distending the joint. The rubber bandage does its work within a week (daily massage may aid), after which it is dispensed with. As the patient lies in bed the rectus muscle is relaxed by keeping the foot elevated and thus flexing the hip. This splint is retained for five or six weeks, splint, plaster, and bandages being renewed as often as necessary. An interval of more than a quarter of an inch between the fragments should be considered unsatisfactory. For the second month a hip splint and daily massage are employed (or a plaster encasement for less opulent patients), the patient being up and about. After this the patient is allowed to go free, but is warned to begin exercising gradually and to be especially careful about stooping, going up and down stairs, and such other motions as involve bending the knee. This period of convalescence requires from one to four months longer.

Operative Treatment.—For the reasons already given I shall describe only one operation. A vertical or U-shaped incision is used, according to the fancy of the operator. The fracture is laid bare and while the fragments are retracted the joint is copiously flushed with warm salt solution until all clots have been washed away. The ragged fringe of periosteum is clipped from the edges of the fragments, after which they are approximated and held together by a periosteal suture of catgut or kangaroo tendon. The rents in the lateral expansions may be similarly caught up and the whole reinforced by a circular catgut suture uniting the quadriceps tendon to the ligamentum patellæ, the strands to lie at each side or in front of the patella. This last suture is rarely necessary. During all these manipulations no finger should touch the tissues. The skin is sutured with silk and the limb is bound to a posterior splint. A week later the silk sutures are removed and a plaster encasement is applied. A week after this the patient goes about on crutches and so continues until the end of the fifth week. After this the splint, preferably a hip splint, is worn only by day and as soon as free flexion is obtainable, during the third month, the splint is discarded altogether; by that time convalescence is complete.

Bony union is expected after operative treatment, fibrous union with an ultimate separation varying from a quarter of an inch to an inch after mechanical union. Yet even in the former case there is usually separation of the anterior edges of the fragments, and bony union may fail after all. In either case restricted motility is rarely due to loss of power. Indeed the quadriceps extensor adapts itself to very wide separations. When some stiffness persists in the joint, as is often the case after mechanical treatment and less frequently after the operative methods, it is due either to organized blood clot within the joint, to prolonged immobilization, or to such a lengthening of the patella as to prevent its slipping smoothly over the condyles. Chopart, who advanced the last theory, excised the upper fragment in one case with marked benefit to the patient. The frequent practical failure of secondary operations which seek to remedy disability by approximating the fragments makes a field for this operation. Slight disability, however, had best be borne as a necessary evil. Refracture may be treated by suture or by splint. Fractures by direct violence are usually associated with little or no laceration of the capsule. Hence there is no displacement and no operation is needed.

FRACTURES OF THE TIBIA AND FIBULA.—*Fractures of the Upper Ends.*—These fractures are rare. They may involve the joint causing hæmarthrosis, may rupture the vessels, and are not infrequently comminuted. Avulsion of the spine of the tibia is a complication of dislocation. Avulsion of the tubercle is an extremely rare result of the muscular action of the quadriceps extensor. Epiphyseal separation at this site has no peculiar features.

Fractures of the Shafts.—These occur commonly at the junction of the lower and middle thirds. The fibula is usually broken at a higher level than the tibia. The fracture of the tibia is often V-shaped and from the point of the V a fissure may descend to the ankle joint. Moreover, muscular contraction usually displaces the lower fragment backward and the sharp point of the upper fragment is likely to pierce the skin either at the time of accident or subsequently.

The fracture of the tibia is readily determined by palpation. The fibular fracture may be neglected unless it occurs alone (by direct violence), in which case pressure along the bone elicits a point of tenderness, and this same tender spot is disturbed by pressure over the shaft of the bone some distance away.

Treatment: Reduction is readily accomplished with the knee flexed to a right angle to relax the muscles. If the tendency to displacement is slight the leg is placed in a Volkmann splint (Fig. 2212) or fracture box (Fig. 2211) for a few days until the primary reaction has subsided, and then later is put up in a plaster encasement, or the advantages of the two splints may be combined in a posterior moulded splint running from the knee to the toes or terminating below in two broad flaps, which overlap over the dorsum of the foot. The Cabot wire frame employed by Scudder also commends itself. Union may be expected at the end of six weeks in simple cases, but if there is much comminution it may be considerably delayed. Such cases as well as all others in which the circulation of the limb is poor are benefited by elevation and daily massage of the injured member, though as routine practice it is best to get the patient out of bed during the first week. Otherwise several extra weeks will be required to overcome the œdema and stiffness felt on first using the limb.

A marked tendency to displacement may be overcome fairly well by traction applied to the ankle. Operative fixation is, however, more generally employed. Ambulatory treatment has been considered elsewhere. A compound comminuted fracture often takes months to heal.

Fractures of the Lower Ends.—Separation of the tibial epiphysis is caused by eversion or inversion of the foot. The line of fracture runs well above the articular surface. The foot is to be immobilized in such a position as to retain the fragment in place. Union may be followed by cessation of growth in the tibia and inversion of the foot from overgrowth of the fibula.

Supramalleolar fractures usually show the same features as epiphyseal separation, but if there is extensive comminution there is the added danger of a stiff ankle.

The fibular epiphysis is often separated in Pott's fracture.

Pott's Fracture.—This is by far the commonest fracture of this region. It is *the* injury of the ankle quite as Colles fracture is *the* injury of the wrist, and yet the rational principles upon which the treatment of this fracture must be based are commonly misunderstood, and Pott's fracture is casually spoken of as an injury from which a perfect recovery is not to be expected. On the contrary, it has been my experience that a good result may and should be expected, and will be obtained by appropriate treatment.

Pott's fracture is caused by indirect violence, a twist of the foot. The twist is outward, causing a "fracture by eversion and abduction." Inversion and adduction cause a simple "malleolar fracture" (see below).

The lesions of Pott's fracture (Plate XXVIII., Figs. 10 and 11) are: (1) fracture of the internal malleolus or rupture of the internal lateral ligament; (2) diastasis of the tibio-fibular joint caused by the rupture of the tibio-fibular ligament with perhaps avulsion of the adjoining bone; (3) fracture or epiphyseal separation of the external malleolus; and (4) an outward and backward displacement of the foot. This displacement is due to the tibio-fibular diastasis, which allows the powerful tendo Achillis to draw the foot backward while the lack of support on each side allows the peroneal muscles to hold the foot in the position of eversion and outward displacement into which it has been forced. Compound fracture, which is rare, is usually the result of excessive or prolonged violence, which forces the internal malleolus through the tense skin of the inner side of the ankle while the foot is held abducted. The fragment of the internal malleolus may be so rotated as to require operative reposition.

The symptoms of Pott's fracture vary between the limits of acute continuous pain with entire disability and a mere aching and soreness without any great loss of function during the first hours after injury. The physical signs are, however, constant and definite. There is more or less contusion about the ankle, and in many cases the outward (Plate XXVIII., Fig. 10) and backward displacement of the foot is so marked that the nature of the injury is manifest. There are, moreover, several pathognomonic signs. Three points of tenderness are always present: one over the line of fracture of the internal malleolus, usually near the tip; a second over the fracture of the fibula, usually at the junction of the shaft and malleolus; and a third in front of the ankle between the bones of the leg marking the site of the ruptured tibio-fibular ligament. Another characteristic sign is lateral mobility in the ankle joint. This is elicited by grasping the foot firmly with one hand (the palm of the hand beneath the sole, the thumb under one malleolus, and the fingers under the other) and moving it bodily from side to side, while the leg is steadied by the surgeon's other hand. If there is lateral mobility the astragalus may be felt to glide smoothly from side to side, and may usually be brought up against one or other malleolus with a distinct click. Abnormal forward and backward mobility may also be elicited. It may be impossible to produce crepitus. Extension and flexion of the ankle is painful, but upward pressure on the heel is not.

Treatment.—The backward displacement and eversion are overcome by drawing the foot forward and inverting it sharply. Comparison with the sound limb will readily determine whether the backward displacement has been corrected; the eversion should, however, be overcorrected, for while there is no danger of the foot becoming fixed in abnormal inversion, hyperinversion pulls the fibular fragment downward and inward into place and at the same time leaves no possibility of any permanent eversion. The foot must be kept at a right angle with the leg.

In splinting care must be taken to maintain the reduction inward and forward and at the same time to prevent a drooping of the foot from traction by the tendo Achillis. Stimson's posterior and lateral plaster splints are admirably suited to this purpose. The posterior splint runs from just below and behind the knee down over calf, ankle, heel and sole, to the toes. The lateral "stirrup" splint begins just below the head of the fibula, and runs down the outer side of the leg, over the sole of the foot (and the posterior splint) and around to the outer side of the dorsum of the foot. The foot is held in proper position while the splints are applied. This apparatus is more secure than wooden splints and allows inspection and correction of the deformity better than the familiar plaster encasement. The patient should be kept in bed a few days with the leg elevated on pillows. He may be allowed about as soon as the primary reaction has subsided (at which time a new splint is usually required). If the splints are not sufficiently strong or are loosely applied, the foot will sag. This is not likely to occur before the second week, when the splints have begun to wear out. The tendency is overcome by applying a new moulded splint, or an orthopædic splint made with a movable foot-piece on two lateral braces of metal, or even a plaster encasement or by dividing the tendo Achillis.

Union is firm at the end of six weeks, but six weeks more are usually required to limber up the ankle joint and to overcome passive œdema. When reduction is properly maintained, a perfect ultimate result may be predicted, if due allowance be made for extreme old age, rheumatism, gout, etc.

Old unreduced or imperfectly reduced fractures are very disabling. The eversion causes a constant drag on the ligaments of the inner side of the ankle, while the backward displacement limits dorsal flexion and makes the gait stilted. The eversion may be corrected by supramalleolar osteotomy, but the backward displacement can be corrected only by opening up the old lines of fracture in the tibia and fibula, chiselling away any exuberant callus, and reducing the fracture as though it were a recent one.

Malleolar Fracture.—The malleoli may be broken by direct violence; but the fracture is commonly caused by inversion of the foot. Only the external malleolus may be broken, usually near its tip, or the internal malleolus as well may be fractured. There is no tibio-fibular diastasis, nor any dislocation of the astragalus, as in Pott's fracture.

The symptoms of disability, pain, and ecchymosis, point to some injury about the ankle joint. Examination reveals one or two points of local tenderness over the external or both malleoli; but there is no tender spot in front of the ankle and the lateral mobility characteristic of Pott's fracture can rarely be demonstrated. Independent mobility of the fragments may sometimes be elicited. In a few cases the fracture of the tibia has been so high as to carry away a large part of the articular surface with the fragment. In such cases lateral mobility and backward displacement of the foot are possible; but the condition may still be differentiated from Pott's fracture by the absence of the anterior tender point, and by recognition of the large tibial fragment, which is displaced upward and inward.

The foot usually requires only fixation at a right angle for five weeks while the fragments unite. When there is any tendency to displacement the foot must be well drawn forward and immobilized in a position of natural right-angled flexion. Hyperinversion would be liable to cause mal-union of the tibial fragment.

The prognosis is generally good, though when the tibial fragment is large the usefulness of the joint may be imperilled by exuberant callus.

Fracture of the Bones of the Foot.—Tarsal Fractures: The bones of the tarsus are rarely broken. The only fractures of any clinical importance are those of the astragalus and os calcis. A compound fracture of either or both is readily diagnosed and is treated according to the surgical and mechanical requirements of the case by antisepsis and excision or reposition of fragments. When the fracture is a simple one, the diagnosis may be impossible without the aid of the *x*-rays. Such cases do well under simple immobilization and massage until the foot will again bear the weight of the body. If a fragment is irreducible it may be excised or replaced by operation. Avulsion of the tendo Achillis does well under expectant treatment. Even when there is marked separation satisfactory union may be anticipated within six or eight weeks.

Metatarsal and Phalangeal Fractures.—These present the same features as the homologous fractures of the hand.

Fracture of the Ribs and Sternum.—*Fracture of the Ribs:* This is one of the commonest of all fractures. It is usually caused by a crushing force, such as a fall upon the chest or a heavy blow. The ribs give and then break. Fractures by direct violence are not uncommon. Multiple fractures are frequent, although the two upper and lower ribs almost always escape. Green-stick fractures occur but usually pass unrecognized. The rib is usually broken between the mammary and mid-axillary lines. Displacement is unusual unless the whole side is caved in. There is localized pain at the point of fracture, which may be elicited by compressing the chest sharply from before backward. Crepitus may be elicited by gentle manipulation of the fragments, and by deep inspiration. It may be inaudible unless a stethoscope is used.

The fracture of a rib is not a matter of great importance. There is usually severe persistent pain for several weeks; yet a contusion may cause as much. There may be puncture of the lung, mediastinum, or heart, resulting in any one of the many conditions due to wounds and contusions of these viscera (*q. v.*); but these internal injuries can and do occur as a result of simple contusion without any fracture, and hence when they occur in connection with fracture it is by no means proved that they are caused by the broken bone. They are not necessarily complications of the fracture, and their symptoms and treatment are not modified by the presence of a broken rib.

Treatment: A strip of adhesive plaster five inches wide and eighteen inches long having been prepared, the patient is instructed to take a deep inspiration followed by a deep expiration. At the depth of expiration the adhesive strap is rapidly applied, beginning at a point close to the spine, on the sound side, and following the curve of the broken bone around nearly to the opposite nipple. This strap, applied as tightly as possible, splints the side and minimizes the movements of respiration which constitute one of the chief causes of pain. Several overlapping straps increase the support. Rest in bed adds to the patient's comfort but is by no means necessary. Union is firm in four weeks.

Fracture of the Sternum: These fractures are rare at best. They are most often breaks at or near the junction of the manubrium and the body of the bone. The lower fragment is displaced forward as a rule. The fracture has been caused by muscular effort. The prognosis depends upon the shock and the internal injuries. Uncomplicated cases do well.

Reduction is accomplished by direct pressure on the displaced fragment aided by hyperextension of the spine, the patient lying over a block or box, and breathing deeply. When manipulative efforts fail, operative reduction may be attempted by such means as drawing the depressed fragment forward with a small corkscrew, or removing the overlapping portion of the anterior fragment. Such operations only may be undertaken with due respect for the vital organs lying directly beneath the bone. *Edward L. Keyes, Jr.*

FRAMBŒSIA. See *Yaws.*

FRANGULA. See *Buckthorn.*

FRANKLIN SPRING.—Franklin County, Georgia.

Post-Office.—Royston.

Access.—Viâ Elberton Air-line Railroad to Royston, thence two miles by hack line to springs. This spring has had considerable reputation as a resort for invalids as far back as the oldest citizen can remember. Qualitative analysis: Iron carbonate, calcium sulphate, magnesium sulphate, sodium chloride, aluminum sulphate, potassium sulphate, iron protosulphate, sulphuretted hydrogen gas.

This water contains sufficient aluminum to render it valuable in chronic diarrhœa and dysentery and useful as a local application in ulcerative skin diseases. The deposit of iron in the spring was used to some extent during the late war to supply the place of copperas. The temperature of the water is 60° F. and the flow two and one-half gallons per minute. The climate is good and near by is some very fine mountain scenery. There are facilities for bathing and the neighborhood offers numerous features of interest. *James K. Crook.*

FRANZENSBAD.—An Austrian village on the frontier of Bohemia, 1,300 feet above sea-level, renowned for its mineral springs and baths, ranking next in popularity to Marienbad, and at present resorted to chiefly by women. The climate is mild, but is subject to sudden change.

The springs are eleven in number, namely: (1) Wiesenquelle; (2) Kalter Sprudel; (3) Franzensquelle; (4) Louisenquelle; (5) Neuquelle; (6) Loimannsquelle; (7) Stahlquelle; (8) Mineral Sprudel; (9) Salzquelle; (10) Oestliche, and (11) Westliche. Of the numerous gas springs in the vicinity, several are used for charging mineral water and to supply the gas baths. The chemical composition of the principal springs varies so little as to hardly justify the usual division of them into four classes.

The Wiesenquelle, Kalter Sprudel, and Franzensquelle are considered therapeutically most important, resembling in composition the springs of Carlsbad and Marienbad. The Franzquelle, "the mineral spring of Egra," is enclosed in a temple-like building. The fount contains 20,000 cubic inches of clear, sparkling water, of about 50° F. the year round, which is, with slight variation, the temperature of the other springs. Exposed for several hours to the atmosphere, the water becomes turbid from precipitation of carbonate of iron. Its taste is agreeable, though slightly ferruginous. The other springs are provided with equally elegant surroundings. The Kalter Sprudel produces 3,648 cubic inches of water a minute, accompanied by an escape of free carbonic acid so abundant as to produce the sound of a boiling caldron. The Louisenquelle is the largest in water supply. Its fount contains 6,861,738 cubic inches, flowing 27,000 cubic inches a minute, and the escape of free carbonic acid is tumultuous.

Composition.—Sodium sulphate predominates in all the springs, varying from 10.897 grains in a pint of the Mineral Sprudel to 26.926 grains in the Kalter Sprudel; the Wiesenquelle containing 25.643 grains. The other ingredients are the carbonates of iron, manganese, sodium, calcium, magnesium and lithium, sodium chloride, calcium phosphate, and traces of silicates.

Indications.—The Franzensbad waters, especially those of the Salzquelle, Wiesenquelle, and Kalter Sprudel, are recommended for: (1) Chronic catarrhs, especially chronic gastritis, constipation and cystitis; (2) hyperæmia and moderate hypertrophy of the liver and spleen; (3) disorders of the uterine system; (4) scrofulous affections and gout; and (5) as an after-treatment to Carlsbad and Marienbad.

The Franzensbad and Stahlquelle have been recommended chiefly for: (1) anæmia after hemorrhage, notably that following repeated miscarriages, and exhausting diseases in scrofulous, rachitic, or scorbutic constitutions; (2) diseases of the abdominal or sexual organs with anæmia; (3) slow development of puberty, chronic uterine or vaginal catarrhs, abnormal menstruation, and (4) nervous diseases, especially the neuroses.

Peat Baths.—These are among the most noted in Europe. The fresh peat has a gray or yellowish-gray color, acid reaction, and an odor of sulphurous acid. It is dug up in the autumn and placed in heaps, where chemical changes occur, forming a large number of sulphates, and the mass becomes jet-black, smooth, and homogeneous. In the bath-house, it is diluted with water from the Louisenquelle and heated by steam to 70° or 80° F. The bath is said to be invigorating to the system as well as stimulating to the skin.

The peat baths are recommended for: (1) anæmia and chlorosis, chronic rheumatism, gout, scrofula, and rickets; (2) various neuroses, paralyses not of cerebral origin, the early stages of progressive muscular atrophy, concussion of the spine; (3) sexual disturbances, a tendency to abortion, prolapsus uteri, loss of virility; (4) to aid the absorption of exudates and the infiltrations of intermuscular connective tissue, synovial sacs, ligamentous structures and glands.

Gas baths are also administered, the entire body, except the head, being enclosed in a chamber resembling the ordinary vapor-bath cabinet. *James M. French.*

FRAXINELLA. See *Rutaceæ.*

FRAXINUS. See *Ash Bark.*

FRENCH LICK SPRINGS.—Orange County, Indiana.

Post-Office.—French Lick Springs. Hotel at West Baden, one mile distant.

This is one of the old spring resorts of Indiana. The springs are thirteen in number, of which several have been analyzed. The flow of water amounts to about eleven hundred gallons per minute. The following analyses are supplied by the United States Geological Reports, and were made by J. G. Rogers, analyst:

One United States Gallon Contains:

Solids.	Proserpine Springs. Grains.	Pluto's Well. Grains.
Sodium carbonate	10.52	
Magnesium carbonate	4.50	1.59
Calcium carbonate	20.29	6.95
Iron carbonate Aluminum carbonate	2.49	Trace.
Sodium sulphate	36.72	22.37
Magnesium sulphate	29.33	18.12
Calcium sulphate	141.00	60.59
Sodium chloride	90.92	140.54
Calcium chloride	......	5.35
Potassium chloride	5.01	
Magnesium chloride	8.05	
Silica	1.69	
Alumina	......	Trace.
Undetermined matter	......	.54
Total	350.52	256.05
Gases.	Cu. in.	Cu. in.
Carbonic acid	10.116	Not determined.
Sulphuretted hydrogen	17.000	

These are very good examples of sulphuretted saline waters, and are useful in those diseases to which that class of water is applicable. They are used commercially at the present time. *James K. Crook.*

FRONTAL SINUSES, DISEASES AND INJURIES OF.—Anatomy.—The frontal sinuses are two irregular-shaped cavities, which extend upward and outward a variable distance between the two tables of the frontal bone, upon the vertical portion of its internal surface. They are situated one upon either side of the base of the nasal spine, between the latter and the orbital plate. They are separated from each other by a thin, bony partition. In size they vary in different individuals, and are, as a rule, larger in the male than in the female sex. The frontal sinus of the left side is commonly the larger of the two. They are sometimes subdivided by incomplete bony laminæ. They open into the middle meatus of the nose through the infundibula, and occasionally communicate with each other by apertures in the septum. They are absent at birth, but appear during the first year of childhood, and remain of small size up to puberty, at which time they undergo considerable enlargement from the recession of the brain. In advanced life they increase in size by absorption of the cancellated tissue in their vicinity. In their development they are practically formed from the diploë. Large frontal sinuses do not necessarily imply large external prominences over the glabella and superciliary eminences. They are lined by mucous membrane, this being continuous with that lining the middle meatus of the nose through the infundibula. This mucous membrane, like that which lines the antrum of Highmore, is notably thin and pale. Its blood supply is derived chiefly from the internal maxillary and ophthalmic arteries, and by anastomosis of these with the lateralis nasi branch of the facial artery. Its nerve supply is principally from the first and second divisions of the fifth cranial nerve. In the middle meatus of the nose the communication through the infundibulum of either side with the frontal sinus is partially hidden, and sometimes practically closed by a projecting fold of mucous membrane.

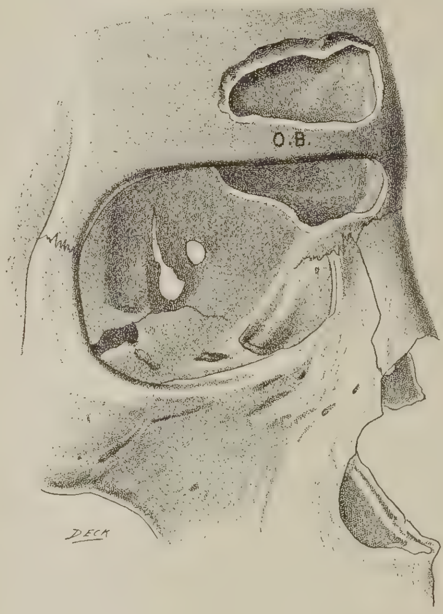

Fig. 2227.—Frontal Sinus, the Anterior and Inferior Walls of which have been Removed, with the Exception of an Osseous Bridge, Corresponding to the Orbital Margin. (After Killian, in Heymann's "Handbuch der Laryngologie," etc.)

Diseases and Injuries.—Owing to the continuity of tissue and similarity of anatomical structure, the affections of this sinus, like those of the other accessory cavities of the nose, resemble to a greater or less degree those of the nasal fossæ proper. They may be conveniently grouped, for purposes of study, under the general headings of inflammations, acute and chronic (frontal sinusitis), and their sequelæ; tumors, the only primary forms described by modern authorities being osteoma and sarcoma; trauma of the sinus wall, which comprises fissure, fracture, impressions, etc., usually associated with hæmatoma of the sinus; and foreign bodies, which are nearly always projectile, but which also comprise insects and their larvæ. Generally speaking, the diseases of these sinuses occur with great infrequency, although trauma is of somewhat common occurrence, by reason of the exposed situation of the anterior sinus wall.

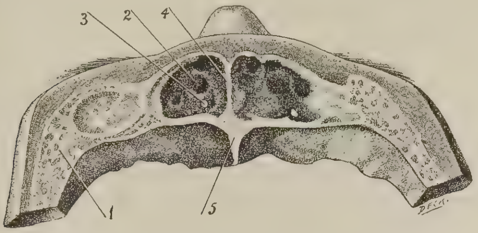

FIG. 2228.—Horizontal Section through the Frontal Sinus. (One-half actual size.) 1, Frontal bone; 2, frontal sinus; 3, aperture of the frontal sinus; 4, septum between the frontal sinuses; 5, frontal crest. (After von Mihalkovicz, in Heymann's "Handbuch der Laryngologie," etc.)

Sinusitis Frontalis.—The acute form of this disease generally results from the extension, by continuity, of a coryza, especially when the latter accompanies influenza. Acute sinusitis is frequently found in autopsies upon those who have died of acute infectious diseases. In this affection the mucosa becomes congested and œdematous, often to the extent of obliteration of the cavity. The exudate is usually purulent, but may be mucous or even serous. A fibrinous exudate is not known to occur.

Of the symptoms headache is the most constant. Constitutional reaction is indicated at times by the presence of fever, vertigo, vomiting, etc. Ocular reflexes are often seen, consisting of lachrymation, photophobia, colored vision, spectra, sense of pressure, etc. Œdema of the upper eyelid and exophthalmus are now known to occur at times.

The secretions, while they may escape to a greater or less extent into the nose, tend to accumulate, by reason of œdematous obstruction of the sinus outlet.

The disease supervenes suddenly in the majority of cases. Its course is brief and usually terminates at the end of the first week in the evacuation of the sinus and the subsidence of the inflammatory œdema which has produced more or less retention of the effusion within the cavity. In a certain proportion of cases, however, this favorable termination does not transpire and the disease then becomes chronic.

Acute sinusitis is often complicated by serious affections due to direct extension of the original malady. Periostitis is common, the orbital wall of the sinus being the principal sufferer in this respect. While this process may terminate in ulceration or necrosis of the bone, with resulting infection of the orbit, the fact is now well attested that the latter cavity may become inflamed without previous organic disease of the bony wall. This extension through osseous tissue without the serious participation of the latter is also seen in the endocranial lesions which occasionally follow acute frontal sinusitis. This mode of termination of the latter affection is attributable in most cases to phlebitis and thrombosis of the veins which traverse the walls of the sinus. In this manner the brain may be imperilled long before sufficient time has elapsed for organic perforation of the bone. Endocranial infection having once occurred, a variety of pathological processes may be set up, including extra- and intradural abscess, meningitis, encephalitis and cerebral abscess, thrombosis of the superior longitudinal sinus, etc.

Chronic frontal sinusitis, while a sequela, as a rule, of the acute affection, may be due exceptionally to one form or there may be several causes. It may undoubtedly result from the extension of an ozæna; or it may be due to a trauma affecting the sinus or its immediate vicinity. Syphilis, tuberculosis, and carcinomata which develop near the sinus may readily implicate the latter, although the present state of our knowledge enables us to state that these serious affections seldom or never originate in this cavity.

There is evidently some special principle involved in virtue of which an acute sinusitis may become chronic. When the sinus first becomes inflamed the anterior ethmoidal cells are usually implicated. When the sinusitis proper undergoes resolution, these accessory cavities may remain inflamed; and from this focus the chronic œdema and polypoid hypertrophy which characterize chronic sinusitis may readily develop. The irregularities which occur in the anatomy of these accessory cells should be reckoned with as factors in individual cases. Finally, one frontal sinus may infect its fellow through perforation of the septum, or this may occur even without any previous solution of continuity in the latter.

The constant pathological features of chronic sinusitis consist of œdema with a certain amount of polypoid hypertrophy. Fibrinous exudation, non-existent in acute sinusitis, may develop in time in the course of the evolution of the chronic type of inflammation.

From the clinical point of view, chronic frontal sinusitis presents two phases, according as the inflammation terminates in dilatation or in destruction of the bony walls and abscess. In the earlier stages of the process symptoms may fail entirely or they may be of the same character as those of the acute type (headache and numerous ocular disturbances of a reflex character).

In regard to chronic sinusitis with termination in dilatation, Killian [1] has collected and analyzed the entire recorded material (some sixty-four cases), with the following results: Dilatation of the sinus may develop at any time from the first to the twentieth year of the disease. The resulting cavity usually attains the size of a pigeon's egg, although it may exceptionally have the capacity of half a pint or more. The orbital wall is the one most disposed to yield to the pressure from within, although the entire bony capsule may suffer. The osseous structures may come to assume the thinness of parchment.

The secretions, the accumulation of which distends the sinus, are usually mucous or muco-purulent, while in rare instances they are serous in quality. The mucous variety is of especial interest, as it represents the condition often described under the name of *mucocele*. The idea of a separate disease with the latter designation appears to have originated in the peculiar qualities of the fluid, which is very tenacious and gelatinous and of variable color. Cholesterin crystals are sometimes obtainable from these collections. "Mucocele" has been held to be of cystic nature, and its inflammatory origin has been unsuspected by many writers. In about three-fourths of the cases of mucocele examined, the outlet of the sinus was accurately closed. Dilatation can occur in sinusitis

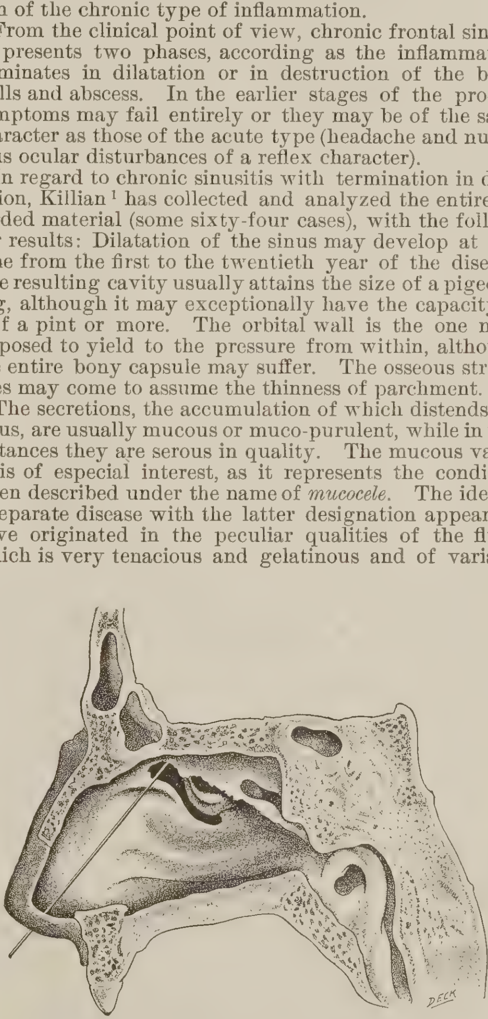

FIG. 2229.—Sagittal Section through the Frontal Sinus, Showing Probe Passed into the Sinus from the Middle Meatus. (After Lichtwitz.)

only in connection with the molecular absorption of bone.

The other mode of termination of chronic sinusitis, viz., in abscess and destruction of the sinus wall, appears to be nearly twice as common as that which is characterized by dilatation. Our knowledge of this destructive type is largely derived from Killian's analysis of the one hundred or more recorded cases. This aspect of sinusitis is eminently chronic, and in not more than a sixth of the cases did the destructive process manifest itself within the first year of the disease. We know that in these cases the sinus must have become infected in connection with an acute sinusitis; and thus the old "retention" hypothesis is rendered untenable.

The first organic change which takes place is ulceration of the lining membrane of the sinus. The denuded bone either becomes carious or secondary periostitis leads to necrosis, with expulsion of sequestra. In the majority of cases these organic changes affect the orbital wall of the sinus. Killian gives the localization as follows: Orbital wall, 66⅔ per cent.; cranial wall, 16⅔ per cent.; frontal wall, 16⅔ per cent.

As in acute sinusitis, a considerable percentage of cases of infection of the orbit and encephalon occur without demonstrable lesion of the bony wall. Of twenty cases of endocranial infection, the bone was perforated in seventeen. The lesion most commonly produced in these cases was cerebral abscess.

The symptoms of the destructive and purulent form of chronic sinusitis vary greatly. Pyorrhœa nasalis may be abundant and fœtid. Pain is often a conspicuous feature. Infection of the orbit, with or without perforation of the orbital wall, tends to the formation of an abscess. Swelling of the lids results, and displacement of the bulbus oculi produces diplopia. Rupture of the abscess produces a fistulous opening, the pus tending to accumulate in the conjunctival sac. The fistula causes shortening of the upper lid. Optic neuritis is occasionally seen as a complication.

The symptoms of endocranial infection closely resemble those which supervene in disease of the middle ear.

In the diagnosis of suspected dilating sinusitis—equivalent to the "latent" sinusitis of some authors—the practitioner should first cocainize the middle turbinate. A nasal speculum with blades adapted for inspection of the middle meatus will render good service in the hands of an expert. But the middle meatus may itself be the seat of inflammation and polypoid hypertrophy; and, furthermore, anatomical anomalies are very common, affecting the turbinates, septum, ethmoid cells, etc.; finally, the operator may not possess the requisite skill to obtain a view of the outlet of the sinus, so that as a routine procedure it is often advisable to resect a portion of the middle turbinate and then make use of the probe or cannula. In employing the probe we must bear in mind that there are at least two fatalities upon record, due to the perforation of the cranial floor by the instrument in question. Experienced operators advise practice upon the cadaver or upon an anatomical preparation, the instrument, a flexible silver probe, being bent at every possible angle to facilitate its introduction.

The old test for the presence of the probe in the sinus was one of mensuration, viz., as soon as the bent end of the instrument is an inch above the anterior process of the middle turbinate, it should be within the sinus. Within the past few years the employment of the Roentgen rays has assisted in the localization of the probe under these circumstances.

If a gush of pus follows the penetration of the probe into the outlet of the sinus, this occurrence might be regarded as *prima facie* evidence of latent empyema, were it not for the fact that certain anomalies of the ethmoid cells are known to occur, in consequence of which we may have to distinguish between frontal sinusitis and anterior ethmoiditis, which affections, more frequently than not, coexist.

If an escape of pus does not take place from probing, the fluid may sometimes be flushed out by substituting a fine cannula for the probe, and forcing air into the sinus.

Second only to the foregoing as a diagnostic resource is the presence of induced tenderness over the sinus. Headache, being a symptom of such common occurrence, is of little value in diagnosis. Tenderness may be elicited at the external and orbital walls of the sinus by percussion and palpation; but simple hypersensitiveness is not pathognomonic, because it has been encountered in hysteria. When tenderness of the orbital wall is associated with thickening due to periostitis, and when orbital cellulitis has already set in, the diagnosis is placed beyond doubt.

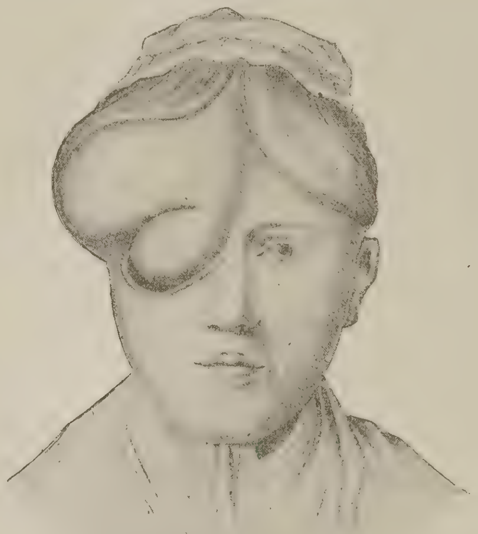

FIG. 2230.—Mucocele of the Right Frontal Sinus. Case of a girl seventeen years of age. (From Gerber's "Atlas der Krankheiten der Nase," Berlin, 1901.)

Chronic empyema of the frontal sinus may lurk beneath the picture of trigeminal neuralgia. Hajek[2] has especially noted this source of confusion in connection with influenza.

In dilatation of the sinus with resulting attenuation of its walls, a yielding and peculiar crackling sound have occasionally been elicited on pressure; these effects resembling those which result from compressing the lid of a tin box.

If the sinus cannot be probed through its outlet, the question of exploratory puncture of the sinus wall must be considered. Opening the floor of the sinus through the nose with an electric drill controlled by lateral illumination of the forehead with Roentgen rays (as advocated by Spiess) appears to be too hazardous a procedure. It is sometimes possible to open an infundibular cell which communicates with the sinus, and an exploratory puncture for this purpose may be safely essayed just in front of the middle turbinate. The method of transillumination of the sinus, while not trustworthy, has exceptionally proved of great diagnostic value. The establishment of an opening from without, for diagnostic purposes, is sometimes justifiable, especially if there is a prospect that the radical operation will be required.

Killian's diagnostic summary is as follows: Simple dilatation is recognized by the local deformity and displacement of the eye, the absence of pain, slow evolution, and parchment-like crackling or fluctuation. Exploratory puncture may be required to differentiate between dilatation and osteoma.

Ulceration is usually announced by circumscribed periostitis, abscess, perforation, fistula, or caries. Pressure over the sinus is often followed by an escape of pus into the nose. Liquids may be forced into the sinus through its intranasal outlet, and they may then escape by the fistulous opening.

Cerebral implication should be easy of recognition; but if this secondary disease pursues a latent course, diagnosis is impossible without laying open and inspecting the sinus cavity. Since the encephalon may be infected without the existence of a perforation, it is often necessary to expose the dura before coming to a definite conclusion. If the dura is healthly, it is extremely likely that the parts beneath are quite intact. If the dura is not in a healthy condition it must be laid open, unless spontaneous improvement follows its exposure. The presence of intrameningeal pus may then be discovered, and a fistula may show that the pus proceeds from a cerebral abscess. In any case the cerebral cortex should be carefully studied, and it may be advisable to puncture the brain for supposed abscess.

Treatment.—Acute sinusitis requires, as a rule, only expectant treatment, consisting of rest in bed; diaphoresis; warm applications to the brow; inhalation of steam; and the administration of such remedies as phenacetin, salol, etc. To the preceding may be added Politzerization and cocainization of the nose.

If these measures do not give relief, the middle turbinate should be resected and the sinus irrigated with warm saline solution. In those rare cases in which the acute formation of pus threatens the encephalon, the sinus should be laid open through its outer wall. It may also be necessary to enter the cranial cavity through the posterior wall of the sinus, split the dura, and give vent to an abscess in the frontal lobe of the brain; or even to extirpate a portion of the cortex. After intervention of this sort, thorough external drainage is all-important.

In chronic frontal sinusitis Hajek is a firm believer in the routine resection of the middle turbinate. He recommends this resource in any case of sinusitis, without regard to the degree or stage of the inflammation. Surgeons and ophthalmologists (and even many rhinologists) do not countenance such a radical procedure, save in special cases. Hajek believes that timely intervention through the nose would often prevent the occurrence of orbital and endocranial complications.

After suppurative complications have occurred, nothing of course is to be gained by resecting the turbinate.

In the majority of cases the operation of turbinectomy is tantamount to a radically curative procedure. Exceptions occur in those cases in which a high degree of destruction has transpired in the mucous lining or bony walls of the sinus.

The immediate results of extirpation of the middle turbinate is an increased amount of secretion. Not until one or two weeks have elapsed do we find a change in the character of the discharge, which then tends to consist of mucus alone. Some secretion remains in evidence for a longer or shorter interval, but in many cases it ceases by the end of the second month.

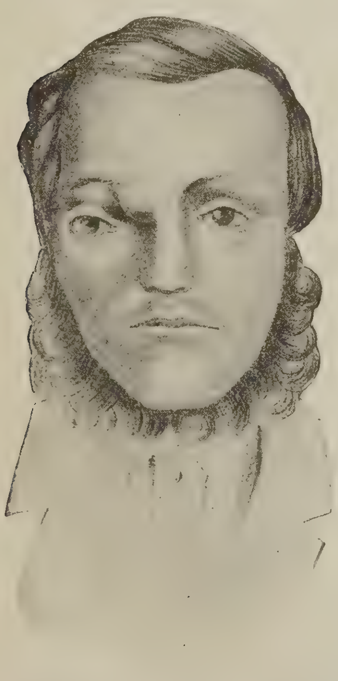

FIG. 2231.—Abscess of the Right Frontal Sinus. Case of a man, forty years of age. (From Gerber's "Atlas der Krankheiten der Nase," Berlin, 1901.)

Hajek has treated 27 cases of chronic empyema according to the principles just enunciated, and has been able to follow up his material indefinitely. In 9 cases the discharge ceased absolutely, while in 11 others it persisted in a mild form. The remaining 7 cases continued to discharge pus, but 4 of these were materially benefited. Hajek regards these figures as equal to the results of complete surgical destruction of the sinus. The patients naturally prefer the conservative form of intervention. Hajek uses the cold snare for the removal of the turbinate, and takes away about one-third of the bone.

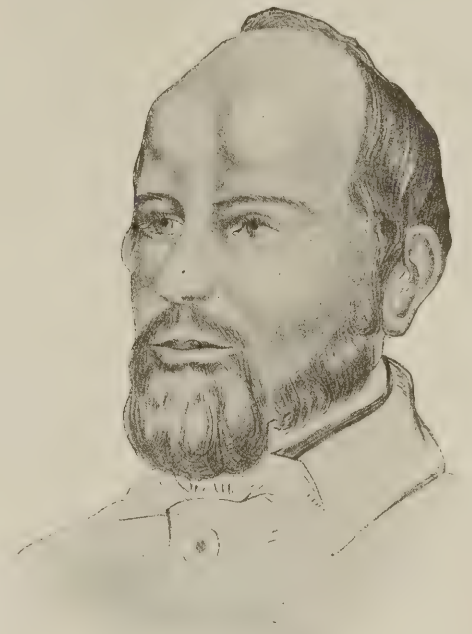

FIG. 2232.—Empyema of Both Frontal Sinuses, with the Formation of a Large Sequestrum of the Outer Plate of the Frontal Bone and of a Tumor Containing Air Beneath the Frontalis Muscle. (From Gerber's "Atlas der Krankheiten der Nase," Berlin, 1901.)

But the intranasal method, which requires special apparatus and skill in its use, has a limited range of applicability; and many surgeons are naturally disposed to regard it as inadequate to answer the indications. Certainly a great variety of procedures have been devised for entering the sinus from without. Originally surgeons had a natural repugnance to opening this cavity, and the earliest form of intervention consisted in following up a fistulous tract. Limited exposure, with application of the actual cautery, was the next step. To-day, the radical procedure of opening directly into the sinus is generally advocated.

Operative procedures have heretofore been divided into simple trephining and the radical operation. Kuhnt combines these two resources into two stages of one operation. For simple trephining, otherwise known as the preliminary or exploratory opening, for the sake of cosmetic effect, the preliminary incision should run from the naso-frontal suture for 3 or 4 cm. along the supraorbital margin, and should reach to the bone. The periosteum should then be pushed upward (often a very difficult procedure), and the sinus wall perforated with the aid of an electric drill and chisel. If the bone is healthy and the mucosa free from polypoid hypertrophy, it is sufficient to irrigate the sinus daily with antiseptics and dust it with iodoform until the opening has healed.

On account of the occasional failure of this treatment, Kocher proposed to extirpate the mucosa of the sinus. This radical intervention may be performed by a number of comparatively new procedures, viz.:

Nebinger-Praun Method.—The anterior wall is opened by horizontal and vertical incisions and entirely removed. The mucosa is curetted, and the naso-frontal duct dilated. The wound is drained through the external opening.

Jansen Method.—The orbital wall of the sinus is removed and the cavity curetted.

Killian's Method.—This consists in opening the sinus through the frontal wall with temporary resection of the nasal bone. The infundibular cells are broken up to such an extent that free drainage of the sinus by way of the nasal fossæ is insured.

Luc-Ogston Method.—Both frontal and ethmoidal sinuses are opened, and a wide communication is established between the former and the nose. A drain is then passed between these two cavities and the external wound closed.

Czerny Method.—Osteoplastic opening of the sinus. Operation finished as in preceding.

Kuhnt's Method.—The anterior wall of the sinus is removed, together with all the diseased mucous membrane and the upper portion of the fronto-nasal canal. This operation is preferred by most surgeons. According to Hajek, the only objection to its general employment is that it makes no provision for attacking the infundibular cells of the ethmoid, which are almost invariably diseased in empyema of the frontal sinus.

Killian sums up the subject of surgical intervention in chronic empyema of the frontal sinus as follows:

The supra-orbital margin must be preserved, even if only a narrow bridge remains; otherwise great disfigurement results. The general theory of most of these operations involves the opening up of a passage between the sinus and nose for the purpose of drainage through the latter. This passage may be natural or artificial. But these communications often heal up prematurely by granulation, and a permanent passage is insured only after resection of the nasal bone or nasal process of the superior maxillary. This form of intervention also gives access to the ethmoid labyrinth.

The technique of Winkler is representative of our modern knowledge of the treatment of chronic frontal-sinus disease. This procedure is as follows:

1. Tampon the posterior nares.
2. Make an incision through the eyebrow (do not shave the latter beforehand).
3. Exploratory puncture through the incision with probing. An alternative now presents itself, viz.: (*a*) Resect the anterior and orbital walls, leaving the orbital margin; or (*b*) perform temporary osteoplastic resection. If permanent resection is to be performed, the technique is as follows:
4. Remove the anterior wall of the sinus with bone forceps or Winkler's saw, the latter being preferable in fixing the upper limit of the orbital bridge.
5. The floor of the sinus is removed with chisel and forceps, the orbital margin being left as a bridge.
6. Extirpation of the mucous membrane of the sinus.
7. The original incision is prolonged beyond the bridge of the nose and beyond the extremity of the nasal bone.
8. The nasal bone and a small portion of the frontal bone are divided with the chisel; the nasal process of the superior maxillary is then divided with the saw.
9. The skin-bone flaps are now turned backward.
10. Diseased ethmoid cells are removed with bone forceps and curette, and a communication is established between the sinus and nose.
11. The flaps are replaced. Sutures may be applied at once or after two days. No irrigation is allowed until two or three weeks have elapsed.

If an osteoplastic procedure has been chosen, the technique is as follows: The skin is pushed back beneath the orbital margin, and the bone separated from the latter with the chisel. At the outer and middle limits of the sinus this margin is chiselled through. The flap of bone and integument is turned upward and outward. All œdematous and fibrous proliferation, carious bone, etc., are removed with the curette.

INJURIES.—In traumatism of the frontal sinus the violence is always direct. Sharp violence is usually due to knife thrusts and sword cuts; while blunt traumatism proceeds from a great variety of objects, including projectiles, flying fragments, etc. The frontal sinus is occasionally injured by horse kicks, blows of the fist, falls upon the face, and the like. The external wall is almost invariably the part injured. Autopsies occasionally reveal the presence of injury of the cranial wall, such accidents being quite generally fatal. The character of the injury varies from simple fissure or indentation to compound fracture and comminution. Hæmatoma of the sinus usually coexists.

The symptoms of injury of this sinus are either local or cerebral. If the violence does not lay open the sinus, the blood escapes by the nose. Epistaxis and pain are practically the sole symptoms of this type of fracture. While these traumatisms tend to recover without sequelæ, the injury doubtless produces sinusitis in certain cases. A peculiar type of traumatism sometimes seen is detachment of the lining membrane of the sinus.

If the cavity is opened subcutaneously by the violence, respiratory movements are seen in the superjacent skin, and subcutaneous emphysema is readily produced, which may extend indefinitely. It tends to subside spontaneously in a few days.

Trauma with complete exposure of the cavity is of frequent occurrence. This class of wounds is readily infected either at the time of the injury or afterward, so that abscess, periostitis, necrosis, fistula, and endocranial complications may result. If infection does not occur, these compound wounds heal readily. One sequela which may occur independently of infection, however, is pneumatocele.

Diagnosis is usually made without any difficulty. In fracture, emphysema readily occurs. Rhinoscopy is useful in detecting hemorrhage from the sinus.

After injury has occurred infection may be prevented by antiseptic irrigation. The possibility of latent injury of the cranial wall must always be borne in mind. As a general rule the treatment of all subcutaneous injuries is expectant, save when cerebral complications are to be feared or when sinusitis develops. On the other hand, open wounds always require active surgical intervention. The opening should be enlarged, the sinus cleaned, spicula of bone and foreign bodies removed, the cranial wall carefully scrutinized for possible injury, and the cavity well drained. Antisepsis will certainly prevent grave endocranial complications. In very extensive wounds a plastic operation is required.

FOREIGN BODIES.—With a very few exceptions all recorded cases of foreign bodies in the frontal sinus have consisted of projectiles, chiefly from old-fashioned weapons. The velocity of modern projectiles, aside from revolver shots, is too considerable for them to be arrested within the sinus.

These projectiles may heal in the sinus, but as a rule a fistula results. Sinusitis is almost invariably set up. These foreign bodies may remain in the sinus for an indefinite period, even amounting to twenty-five years.

Diagnosis was formerly by no means easy, and exploratory incisions were occasionally necessary. To-day the employment of the Roentgen rays insures rapid recognition of foreign bodies in this locality.

A special type of foreign body in the frontal sinus is the animate, consisting of mature insects or larvæ which reach this cavity by way of the nasal chambers. The recorded material, however, is almost all ancient.

NEW FORMATIONS.—Of benign tumors of the sinus, osteoma is the only one which receives consideration from modern authorities, for polypi and cysts are now regarded as incidental features of chronic sinusitis. Even osteomata are held by some to be of inflammatory origin. They may be attached to the bone by a broad base or peduncle, or they may be simply embedded in the mucosa.

They may even lie loose in the sinus. These formations are practically confined to the periods of childhood and adolescence.

In structure the nucleus and peduncle are cancellous and the rest of the mass of ivory-like hardness. The osteoma may attain the size of an apple. Its growth beyond a certain limit expands the walls of the sinus. The cranial cavity is often encroached upon, as are also the opposite sinus and orbit; but so gradual is the enlargement that little functional disturbance results. Exceptionally, severe ocular disturbances, cerebral compression, etc., are produced.

Osteoma may be complicated with sinusitis in all its phases. It also closely simulates dilating sinusitis, so that exploratory puncture may be necessary for differentiation.

The indication in osteoma is immediate extirpation. In former years the mortality from this intervention was very great. As the operation itself is not difficult, the danger must lie solely in the possibility of infection.

Of malignant growths originating in the frontal sinus such a small number are upon record that hardly anything need be said on the subject. The few cases in literature were all sarcomata, which grew rapidly and broke into the contiguous cavities. Carcinoma has never been known to originate in the sinus, and even the cases of secondary invasion are of extremely rare occurrence.

George Ryerson Fowler.

FRY'S MINERAL SPRING.—Jasper County, Iowa.

POST-OFFICE.—Colfax. Hotels: Fry's and five others.

This is one of a group of ten well-known mineral springs located at Colfax, on the line of the Chicago, Rock Island and Pacific Railroad. Like all the others of the group, this spring has an artesian flow and proceeds from a depth of between 300 and 400 feet. The water of this spring has been analyzed by Dr. Heinrichs, Professor of Chemistry, Iowa State University, and also by Professor Haines, M.D., Chair of Chemistry and Toxicology, Rush Medical College, Chicago. The results obtained are as follows:

ONE UNITED STATES GALLON CONTAINS:

Analysis by Dr. Heinrichs.		Analysis by Dr. Haines.	
Solids.	Grains.	Solids.	Grains.
Sodium chloride	3.85	Sodium chloride	3.842
Sodium sulphate	78.86	Sodium sulphate	77.344
Potassium sulphate	.41	Potassium sulphate	.620
Magnesium sulphate	31.87	Calcium sulphate	31.750
Calcium sulphate	13.07	Magnesium sulphate	10.230
Calcium carbonate	17.51	Magnesium bicarbonate.	25.939
Iron carbonate	.67	Iron bicarbonate	.258
Silica	.29	Alumina	.058
Lithia	Trace.	Silica	.710
Carbon dioxide	7.18	Organic matter	Trace.
Total	153.71	Total	150.751

As seen by the analyses, the water is quite strongly impregnated with mineral ingredients, but not sufficiently so to mar its pleasant taste. Ample bathing facilities are provided. The elevation of the location is 1,100 feet above the sea-level, the surrounding country being of a hilly character. The waters of the spring have been found efficacious in rheumatism, dyspepsia, general debility, and in diseases of the blood, liver, kidneys, and nervous system.

James K. Crook.

FULTON WELLS.—Los Angeles County, California. Hotel and cottages. This resort is located about three miles north of Norwalk station on the Los Angeles Railroad, and thirteen miles from Los Angeles City. The wells were bored by Dr. Fulton, and the resort is conducted by that gentleman. The two principal wells are 350 feet deep and flow copiously. Anderson's analysis shows the following results:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	9.60
Sodium bicarbonate	2.90
Sodium sulphate	.95
Magnesium bicarbonate	17.46
Ferrous carbonate	11.75
Calcium carbonate	12.62
Calcium sulphate	23.41
Silica	2.56
Organic matter	Trace.
Total	81.25
Free carbonic acid gas	Excess.
Free sulphureted hydrogen	Excess.

Temperature of water, 64° F.

This water may be described as a heavy alkaline-chalybeate. It enjoys considerable reputation in the treatment of anæmia, malarial troubles, atonic dyspepsia, congestion of the liver, etc. A large hotel, comfortable cottages, and excellent bathing facilities have been provided for guests.

James K. Crook.

FUMITORY.—The plant *Fumaria officinalis* (fam. *Fumariaceæ*), an annual herb with branching stem, smooth and glaucous compound leaves, and small, rather irregular flowers in axillary racemes; the pods are one-sided, and the juice of the stems and leaves is not milky; in other respects of structure it accords with the poppy family. Fumitory is indigenous to Europe, and an introduced plant in the United States.

The leaves or the flowering herb are collected for use; they have a bitter, saline taste but no odor. They contain a crystalline, bitter alkaline base, *fumarine, fumaric acid,* and a large amount of carbonate of soda.

Fumitory is an old European house remedy for "visceral, obstructive, hepatic, and scorbutic troubles." It is but little employed at present.

ALLIED PLANTS.—*Corydalis* and *Diclytra* ("Dicentra") are pretty flowers, some species of which are cultivated for ornament, and yield drugs which are used to a slight extent. There are several other species of *Fumaria* which have been employed also in medicine.

W. P. Bolles.

FUNGI, EDIBLE AND POISONOUS.—The fungi include a series of plants of very diverse characters, varying among themselves as widely in size, structure, and other characters as do the higher and better known seed-bearing plants. All, however, possess the common characteristics of absence of chlorophyl and some method of reproduction by spores. The first character will distinguish the fungi from other cellular plants like the algæ, while the latter will distinguish them from higher parasitic plants like the dodders, beech-drops, and broom-rapes. All fungi, lacking chlorophyl, must live on some form of organized matter; this they may derive directly from living plant or animal tissues, in which case they are true parasites; others and by far the greater number draw their nourishment from dead or decaying matter and are known as saprophytes.

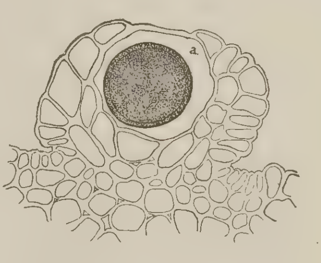

FIG. 2233.—*Synchytrium mercurialis*, producing a Gall on the Epidermis of *Mercurialis perennis*. The fungus is parasitic in a single cell and the resting spore shown at *a*. (After Woronin.)

In structure, some of the simplest consist of minute, naked masses of protoplasm living parasitically within a single vegetable cell which may be a pollen grain, a diatom, the cell of a filamentous alga, or an epidermal cell of one of the higher plants (Fig. 2233); others, like yeast, consist of single cells enclosed in a cellulose covering which does not differ essentially from that of the higher plants; these cells are free floating and derive their nourishment either from saccharine solutions or those containing amylace-

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[1] Killian: Heymann's Handbuch der Laryngologie und Rhinologie, Bd. iii., 1900.

[2] Hajek: Pathologie und Therapie der entzündlichen Erkrankungen der Nebenhöhlen der Nase, Leipzig u. Wien, 1899.

ous substances capable of being transformed into sugar. The more highly organized fungi consist of fine thread-like filaments known as hyphæ which develop primarily from the germination of spores; these hyphæ may be either septate or form continuous capillary tubes and often form a web-like tangle known as mycelium; such a mass entangled with compost, forms the so-called "spawn" from which the ordinary mushrooms of cultivation are grown, and such are the cobwebby films of mould seen on manure piles or on the surface of fruit exposed to a warm moist air. At other times numerous threads of the mycelium become joined to form cord-like strands which sometimes attain the length of many feet. Many of the conspicuous forms of fungi such as the puffballs and ordinary mushrooms are compacted masses of mycelium variously hardened and sometimes mingled with more or less vesicular cells of various sorts; some very hard tissues like those of the woody bracket fungi are developed in the same way, the hardness and toughness depending on the compactness of the fibres and the thickening of their cell walls. The ordinary structures we know as mushrooms, for example, consist merely of the reproductive portion of the plant, and in a general way correspond more or less closely to the fruit of the higher plants; the vegetative portion frequently consists of extensive masses of mycelium concealed underneath the ground, and ramifying in every direction to secure from stores of decomposing vegetable matter the supply of nourishment necessary for their life. This not only serves for their food but from it they manufacture the material from which the reproductive parts above ground are rapidly developed at an opportune time.

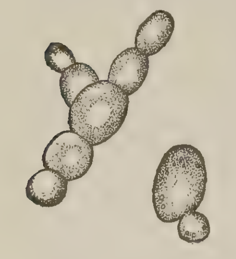

FIG. 2234.—Yeast Cells of *Saccharomyces cerevisiæ* Budding Normally.

Besides developing fungus cellulose which differs only slightly from ordinary cellulose in its reactions, various fungi develop various carbohydrates like sugar, mannite, glycogen, gums, and the like; organic acids especially oxalic, malic, and citric; aromatic acids, fats, ethereal oils, coloring matters of diverse types, resins, albuminous compounds, and alkaloids. The last-named compounds are the sources of poisons found in various mushrooms; while to various combinations of some of the former are to be attributed the nutritious properties and flavors of the various forms of edible mushrooms.

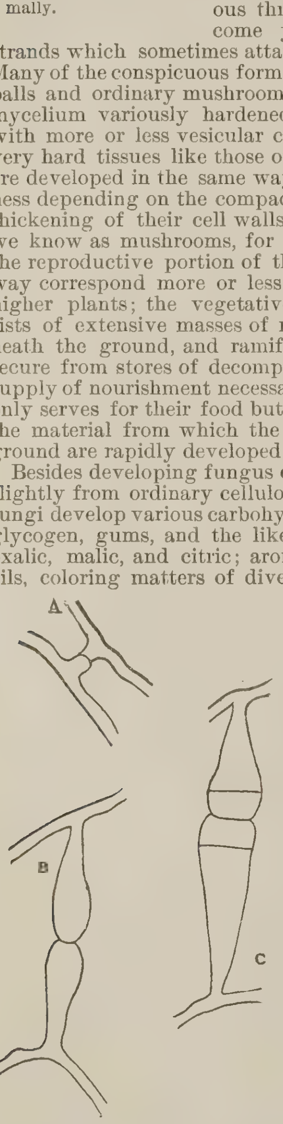

FIG. 2235.—Process of Conjugation in *Mucor stolonifer*, One of the Mucorales. *A*, Two hyphal branches approaching; *B*, the same still further advanced; *C*, suspensors cut apart from the conjugating cells (*gametes*) by septa. The union of the gametes finally produces a zygospore as seen in Fig. 2245. (After De Bary.)

Reproduction is accomplished in various ways. In unicellular forms it may take place by budding (*gemmation*) as in the yeast (Fig. 2234), by self-division (*fission*) as in the bacteria, or by free cell formation (*internal cell division*). In one of the great classes of the fungi, the spores are produced in membranous sacs called *asci* (Fig. 2241), and in the common mushroom they are borne on spicules (*sterigmata*) which rise from enlarged cells known as *basidia* (Fig. 2242). In the various groups of fungi reproductive bodies are produced in a variety of ways which has given rise to an extensive diversity of terms in common use in various works on fungi; some of the more common of these forms are as follows:

1. *Sexual Methods of Reproduction.*

(*a*) By the union of similar elements (*conjugation*) resulting in the formation of a so-called zygospore; the sexual method of reproduction in the ordinary black mould of bread is an example (Fig. 2235).

(*b*) By the union of dissimilar elements resulting in the formation of an oöspore; the sexual reproduction of the downy mildew found parasitic within the leaves of many plants in a good example (Fig. 2236).

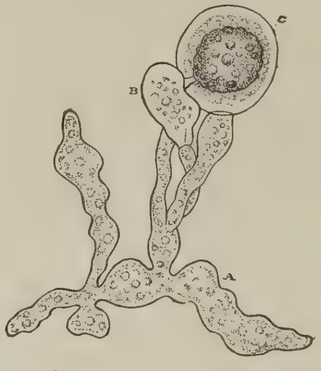

FIG. 2236. — Sexual Reproduction of *Peronospora*; *A*, Mycelium; *B*, antherid; *C*, egg. These structures form inside the leaf of the host.

(*c*) By the union of dissimilar elements, which, followed by the growth of an alternate stage (known as a sporophyte), results in the formation of a sporocarp or so-called spore fruit such as is seen in the common surface mildews of many common plants (Figs. 2237).

2. *Asexual Forms of Reproduction.*

(*a*) The formation of ciliated swarm spores within the cell by the ordinary processes of internal cell division.

(*b*) The formation of solitary conidia on simple or branching hyphæ as in the mould-like growth of the downy mildew that appears on the under surface of many leaves (Fig. 2248).

(*c*) The formation of conidia in chains by the successive cutting off of the ends of certain hyphæ as in the common green mould (Fig. 2252, *C*), the powdery mildew (Fig. 2253, *A*), and the peach rot (Fig. 2238).

(*d*) The formation of sporangia or membranous receptacles containing large numbers of spores formed by a process of internal cell division. Such a type is readily seen in the ordinary method of reproduction of the common mould of manure (Fig. 2246).

(*e*) The formation of pycnidia or special receptacles of more or less elaborate structure, from the walls of which the conidia are produced; such a structure is found in the ordinary leaf-spot disease of the pear (Fig. 2240) and other similar parasitic and often saprophytic fungi.

While many terms are employed for the various reproductive bodies of fungi, it is perhaps better to use only the two terms conidia and spores. In the lower fungi in which there occurs both a sexual and an asexual method of reproduction the term spore is limited to the sexual product, and the term *conidium* (plu. *conidia*) to the asexual. Following the same analogy the characteristic final or mature reproductive body in the higher fungi is also called a spore, even though it does not repre-

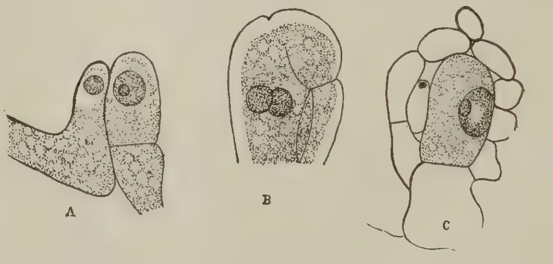

FIG. 2237.—Stages in the Sexual Process of *Sphærotheca Castagnei*, one of the common Powdery Mildews. At *A*, the two sexual cells are distinct; at *B*, they are fusing; and at *C*, the young sporocarp is forming. The mature stage of the sporocarp is shown in Fig. 2253. (After Harper.)

sent the result of sexual reproduction, while any earlier or simpler methods of reproduction are regarded as conidial. Following the same analogy, the spore production among the hosts of imperfect fungi (*fungi imperfecti*) is also regarded as conidial.

By the above discussion it will be seen that the same fungus possesses more than one method of reproduction, and the case is complicated when a parasitic form has one stage of its growth on one plant and the spores or conidia of this stage are then transferred to another host plant and the final growth and a different method of reproduction take place in its new place of abode. Still more complicated are the many cases in which a fungus is parasitic during its conidial stage and passes through its spore-producing stage on some organic substratum as a saprophyte.

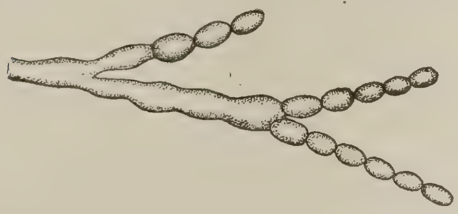

FIG. 2238.—*Monilia fructigena*, the Common Rot of Plums and Peaches; a fragment of a hypha bearing spores produced in chains.

Fungi are of economic importance in a great number of ways: 1. As household pests they invade fruit either fresh or preserved, cereals or other starchy cooked foods, cheese, clothing, and many other things under the name of moulds. 2. As parasites on living plants they prey upon fruits, grains, grasses, the foliage of shade trees, weeds, and many other plants in the form of leaf blights, mildews, rusts, smuts, leaf spots, anthracnoses and the like, often causing immense losses to farmers and fruit growers. 3. As aquatic parasites they attack fish, particularly the young fish in the hatcheries, and often cause considerable destruction. 4. As aerial parasites on living animals they attack flies, grasshoppers, clover weevils, the pupæ of moths and butterflies, and many other animals, sometimes even producing skin diseases in man. 5. In laboratory work with bacteria they often form a disturbing element and a knowledge of their kind and nature becomes a necessity to those who make extensive plate cultures and tube cultures. These moulds are likely to be either (*a*) True Mucoraceæ, (*b*) Conidial stages of certain Aspergillaceæ like the common green mould, or (*c*) Hyphomycetes or moulds with only a conidial reproduction; in some of the latter the spores are light-colored, in others they may be dark-colored or even black.* 6. As agents of fermentation they form the active element of yeast and so are directly concerned in the production of bread and beer, and in all alcoholic fermentation, as well as in the later stages of acetic fermentation. 7. As an article of food they are extensively in use among all peoples whether civilized or not. 8. As destructive agents of timber either in living standing trees or in the form of ties or building material they form a prominent factor in engineering. 9. As remedial agents they are directly concerned with medicine, and finally as malignant poisons they appeal to members of the medical profession for the treatment of the victims of their work.

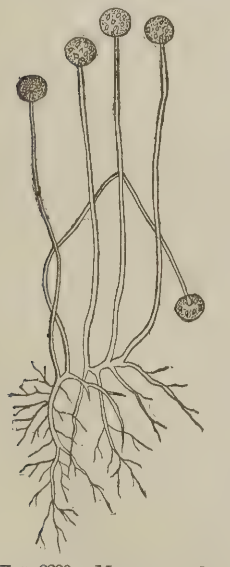

FIG. 2239.—*Mucor mucedo*, showing Root-like Hyphæ and Sporangia filled with Spores at the Summit of Aerial Hyphæ.

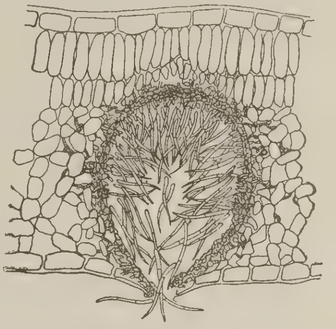

FIG. 2240.—Section of a Pear Leaf taken through one of the Pycnidia of a Leaf Spot caused by *Septoria pirina*. The darkened portions are caused by the fungus mycelium and the spores are formed from the inner wall of the pycnidium and escape at its mouth. (After Duggar.)

There are three principal groups of fungi that may be distinguished as follows:

CLASS I. PHYCOMYCETES — the algal fungi, including mould-like saprophytes as well as various parasites of both animals and plants. These in addition to the more ordinary method of asexual reproduction have a sexual method not unlike that which occurs among various forms of the simpler green algæ, and many of them in fact appear to be little short of degenerate algæ that have lost their power of developing chlorophyl and with it the power of fixing carbon from the carbonic oxide of the air.

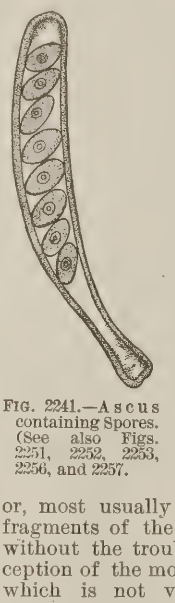

FIG. 2241.—Ascus containing Spores. (See also Figs. 2251, 2252, 2253, 2256, and 2257.

The other two classes of fungi represent distinctly higher types of fungi, whose relations to other members of the plant world are not so clearly marked. These classes are distinguished from the above by their more complicated structure and by the rarity of sexual processes, and are distinguished from each other by the method of spore production which is very characteristic and easily determined in mature material.

CLASS II. ASCOMYCETES, or spore-sac fungi, are characterized by the production of spores in membranous sacs known as *asci* (sing. *ascus*) (Fig. 2241). This character can be readily seen in any mature fungus by making a section for the microscope and examining it for the sacs containing the spores, or, most usually they can be made out from crushed fragments of the spore-bearing surface of the fungus without the trouble of making sections. With the exception of the morels common in spring and *Gyromitra*, which is not very common with us, none of the larger fleshy fungi belong to the Ascomycetes, but rather to the next class.

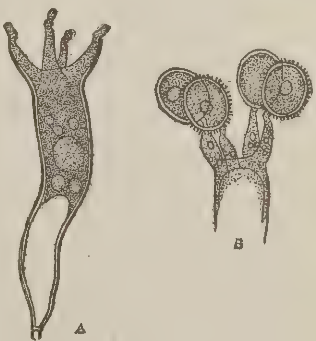

FIG. 2242.—Two Basidia. *A*, With sterigmata bearing very young spores, and *B*, a later development with spores mature.

CLASS III. BASIDIOMYCETES. — These are characterized by bearing the spores naked on enlarged cells known as basidia (Fig. 2242). This class includes besides the parasitic rusts and smuts, all the ordinary mushrooms and toadstools (except the morel noted above), bracket fungi so commonly shelving from trees and stumps, puff-balls and stink-horns, thus including the largest number of conspicuous forms of fleshy fungi as well as the principal forms which contain poisonous principles.

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* A preliminary paper on these forms has been prepared by Dr. Jelliffe, "Some Laboratory Moulds." Journal of Pharmacology, Nov., 1897.

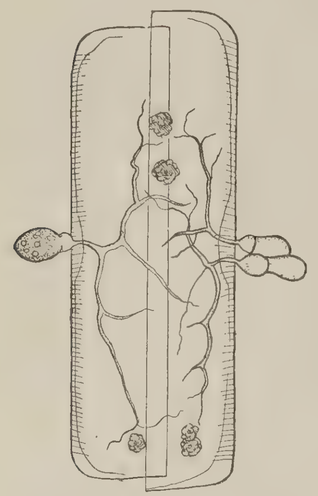
FIG. 2243. — *Septocarpus corynephorus*, One of the Chytridiales, Parasitic on a Diatom. (After Zopf.)

Besides the above groups there are two others closely related in habit and often associated with fungi. These are the bacteria which form the great group often known as the *Schizomycetes* which find a closer alliance with the blue-green algæ (*Cyanophyceæ*), and the slime moulds or *Mycetozoa* which find their alliance in the active form at least with certain of the lowest animals. In their later stages they have some superficial relations with the puff-balls, but really stand at the opposite extreme of the scale.

The general literature on the subject of the fungi is very extensive, but large portions of the earlier writings are now of interest from a historical standpoint mainly. For advanced students of the subject, De Bary's "Comparative Morphology and Biology of the Fungi, Mycetozoa and Bacteria," is still the standard treatise, though it should be supplemented by Brefeld's antagonistic views in his "Untersuchungen aus dem Gesammtgebiete der Mykologie," published in twelve quarto parts (1872–1895). A summary of Brefeld's system may be found in von Tafel's "Vergleichende Morphologie der Pilze" (1892). For the physiology of the fungi, the best general treatment is found in Zopf's "Die Pilze," found in Schenck's "Handbuch der Botanik" (1890), but this must be supplemented by later investigations.

The literature relating to the American fungi is copious but very much scattered and except for synopses of certain small groups no manual or descriptive flora of our American species has been attempted. A guide to the systematic study of the American species with full generic synopses and extended references to our scattered literature is found in Underwood's "Moulds, Mildews and Mushrooms" (1899), and this will serve as a general introduction to the study of our fungi. The literature bearing on particular groups and that relating to the edible species will be referred to under special heads.

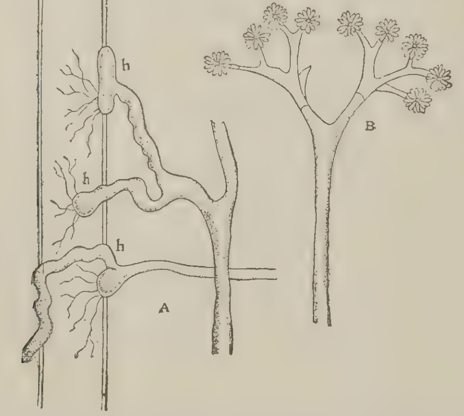

FIG. 2244.—*Piptocephalis freseniana*, a Mould Parasitic on *Mucor*. *A*, Portion of hyphæ showing the haustoria, *h*, *h*, *h*, by which it is attached to the hypha of *Mucor*; *B*, conidia. (After Brefeld.)

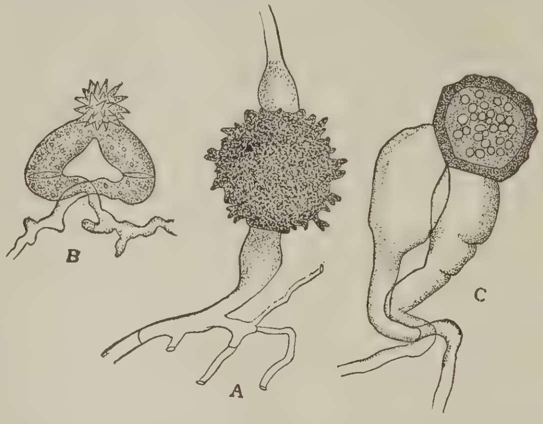

FIG. 2245.—Various Forms of Conjugation in the Mucorales, showing the Zygospore Formation. *A*, *Mucor mucedo*; *B*, *Piptocephalis freseniana*; *C*, *Pilobolus crystallinus*. (After Brefeld.)

CLASS I.—PHYCOMYCETES (*Algal Fungi*).

The Phycomycetes contain five orders of plants:

1. CHYTRIDIALES, which are mostly unicellular endoparasites on algæ, diatoms, infusoria, or rarely on the higher plants; their organization is extremely simple (Fig. 2243) and their method of reproduction is for the most part asexual. Except for the parasitic species of *Synchytrium* (Fig. 2233) the forms have not been studied in this country.

2. MUCORALES, containing the common black-moulds of the household, reproducing asexually by conidia produced either in sporangia as in the common *Mucor mucedo* and *Mucor stolonifer* (Fig. 2239) or more rarely in clusters at the ends of branches as in *Piptocephalis* (Fig. 2244, *B*). A second but less usual method of reproduction is sexual by conjugation as is seen in *Mucor* (Fig. 2245, *A*), *Piptocephalis* (Fig. 2245, *B*), or *Pilobolus* (Fig. 2245, *C*). The last-named fungus is a beautiful but ephemeral plant which appears in crystalline clusters on the surface of horse manure either in stables or often in the open woods. Its sporangial form is most commonly seen as in Fig. 2246.

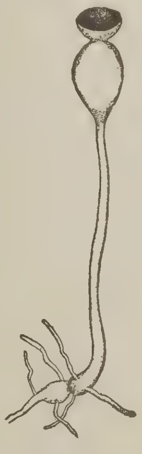
FIG. 2246.—Sporangium of *Pilobolus Kleinii*, one of the Crystalline Moulds Growing on Horse Manure. (After Brefeld.)

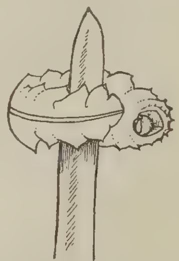
FIG. 2247.—A Larva of the Clover Weevil Affected with *Empusa*, one of the Entomophthorales, coiled about the top of a blade of grass, which is the usual position assumed in the last stages of life. (After Arthur.)

3. ENTOMOPHTHORALES, with similar methods of reproduction as those noted on the last order, but differing widely in habit, living parasitically on insects which they destroy after feeding on their substance. A most familiar example is seen in the fly fungus in which the infested insect attaches itself to a window pane or the wall and becomes surrounded by a halo of white formed by the

conidia. Another species attacks the clover weevil in its larval stage, when the worm crawls to the top of a blade of grass, coils itself around in a regular way and dies (Fig. 2247). Another form attacks the ordinary grasshopper, and he crawls up to a convenient thistle or mullein stalk and dies clasping his perch in a death grip.

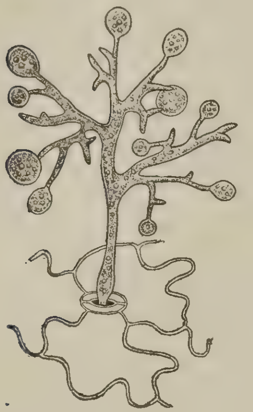

Fig. 2248.—Conidiophores of *Peronospora* emerging from a Stoma on the Under Side of a Leaf, and Bearing Conidia of Various Degrees of Development. (After Kny.)

4. Saprolegniales are water moulds which grow either saprophytically on dead flies or dead fish in the water which is their usual habit, or occasionally become destructive parasites of young fish in hatcheries or more rarely in open streams. Their methods of reproduction are quite similar to those described in the next order, except that they are primarily adapted to the aquatic habit of the plant producing them.

5. Peronosporales, including the downy mildews and the white rusts parasitic on many cultivated plants and occasionally occurring on weeds and wild plants. The potato rot and the downy mildew of the grape leaf which also produces brown rot* in the fruit represent two widespread and destructive diseases caused by members of this order. Reproduction is asexual by means of conidia forming mould-like patches on the under surface of the leaf formed of the minute tree-like conidiophores which bear dust like conidia (Fig. 2248). This method of reproduction is for the purpose of rapidly spreading the disease. A second method of reproduction is sexual by means of the direct fertilization of an egg cell by a differentiated male cell known as an antherid (Fig. 2236); this takes place within the substance of the leaf, and the resting spore resulting from the process of fertilization remains over winter, and on germinating in the spring produces a new crop of the mildew. The mycelium of the fungus penetrates the interior tissues of the plant and draws the nourishment from the cells by means of haustoria, as seen in Fig. 2249. A second member of this order forms the white rust of common crucifers, being most common on shepherd's purse and radish. In this species (*Albugo candida*) the conidiospores are borne in chains (Fig. 2250), many parallel rows forming a white blister underneath the epidermis of the plant. Other species are found on the Canada thistle, amaranth, morning-glory, salsify, and ragweed.

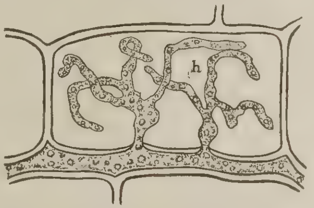

Fig. 2249.—Mycelium of *Peronospora* between the Cells of its Host and Sending Haustoria, *h*, into the Cell. (After Kny.)

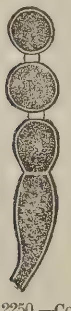

Fig. 2250.—Conidia of *Albugo candida*, the White Rust of Crucifers, Borne in Chains. (After De Bary.)

The best systematic treatment of the groups of this class, particularly the orders Mucorales and Chytridiales, may be found in Rabenhorst's "Kryptogamen Flora Deutschlands, Oesterreichs und der Schweiz," Pilze, Abtheilung IV. Only the parasitic species and the water moulds have been specially studied in our flora by Farlow, Thaxter, Humphrey, and Swingle.

CLASS II.—ASCOMYCETES (*Spore-sac Fungi*).

As stated above, the Ascomycetes are characterized by the fact that they bear their spores in asci or membranous sacs. Besides this method of spore production some of them have other methods of reproduction by means of conidia and other forms of asexually produced spores. The reproductive processes are sometimes complicated by the fact that the different stages of the reproduction are borne on distinct plants and appear at different times of the year, and moreover bear little resemblance to each other. For example, the common ergot appears as a parasitic mould-like fungus in the flowers of rye at one season of the year followed by the formation of the dark hard kernels that take the place of the rye grains and that are known officinally as ergot. The ascosporic stage of the fungus does not appear until the following spring, when the kernels (*sclerotia*) of ergot, after lying on the ground all winter as they do in nature, send up short stems which bear rounded heads in which the perithecia bearing the asci with their spores are found.

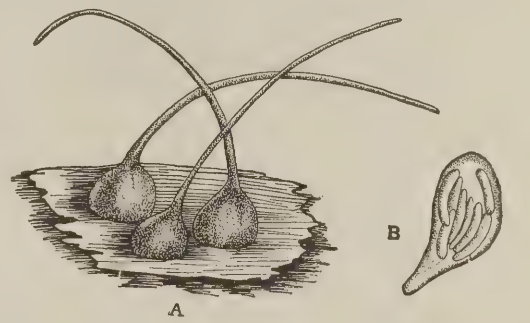

Fig. 2251.—*Ceratostomella pilifera*, one of the Saprophytic Sphæriales. *A*, Three perithecia on a fragment of decaying wood showing the long-beaked perithecia; *B*, ascus, containing the allantoid spores. (After Lindau.)

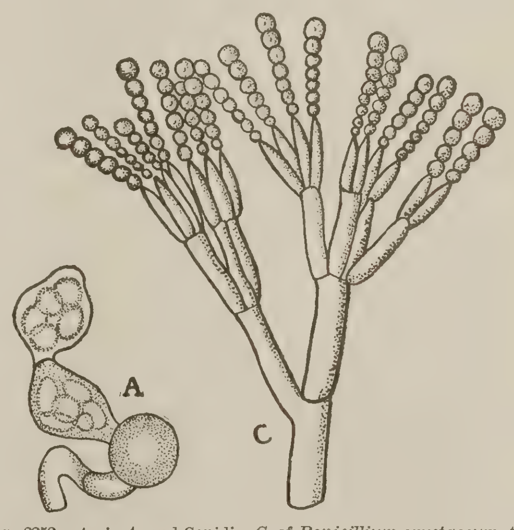

Fig. 2252.—Asci, *A*, and Conidia, *C*, of *Penicillium crustaceum*, the Ordinary Green Mould. (After Brefeld.) The asci are formed in chains.

The asci in the simpler forms are naked and more or less separate from each other; in successively higher forms the asci are found in rounded perithecia (Fig. 2253), in conical perforate perithecia (Fig. 2255, *B*), or in long-beaked perforate perithecia (Fig. 2251); in some cases the perithecia are free from each other and in others, as in the common *Xylaria polymorpha* (Fig. 2254), they are embedded in a stroma composed of compacted hyphæ often very hard. The great majority of the members of this class of fungi are small and inconspicuous; only a few are fleshy and at the same time of sufficient size to warrant their use as food.

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* Not the *black rot* of the grape which is caused by a very distinct fungus.

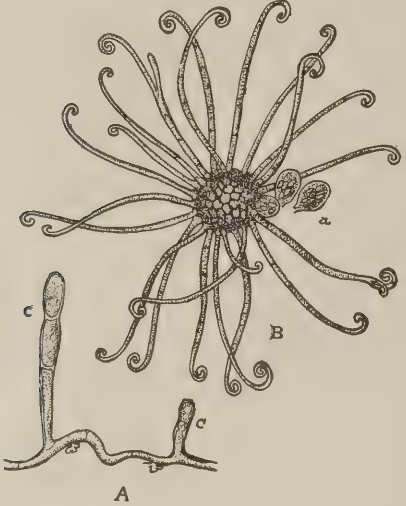

Fig. 2253.—Reproduction of *Uncinula necator*, the Powdery Mildew of the Grape. *A*, Conidial stage showing two conidia at *c*, and one just forming at *c'*; *B*, sporocarp, the result of the sexual process shown in Fig. 2252, showing the escaping asci at *a*. (After Scribner.)

Besides less conspicuous orders the more common forms of Ascomycetes are included in the following orders:

1. Saccharomycetales.—These include the yeast plants which are of economic importance in all matters connected with fermentation. In these the ordinary method of reproduction is by budding (Fig. 2234), but under certain conditions of nutrition they form what have been regarded as free ascospores four in a cell.

2. Aspergillales.—In this group are found two types of fungi, both, however, agreeing in bearing the asci in skeins or chains. One of these types is the common green mould which is well known in its conidial form (Fig. 2252, *C*), but less so in its ascosporic form (Fig. 2252, *A*). The other type of the order is an underground form resembling a truffle but reputed poisonous. It is, however, too small and too uncommon to be considered worthy of much attention here.

3. Perisporiales.—This group includes, besides a few less conspicuous plants, the important group of the Erysiphaceæ or powdery mildews, which are commonly found as parasites on a wide range of hosts among which may be mentioned the hop, grape, gooseberry, lilac, and many others. The perithecia are attached to the surface of the leaf of the host rising from a cobwebby mycelium which draws its nourishment from the epidermal cells; the perithecium is developed from a rather obscure but no less certain sexual reproduction, shown in Fig. 2237, and develops a series of curious appendages around its periphery which are often of complicated and beautiful structure. The perithecia are spherical and imperforate, but they can be easily ruptured under a cover glass when the asci and spores may be studied (Fig. 2253, *B*). A little earlier in the season the conidia are developed (Fig. 2253, *A*) and by their means the mildew is rapidly spread over other plants. The group has been carefully studied by Salmon* and furnishes a delightful introduction to the study of the parasitic fungi.

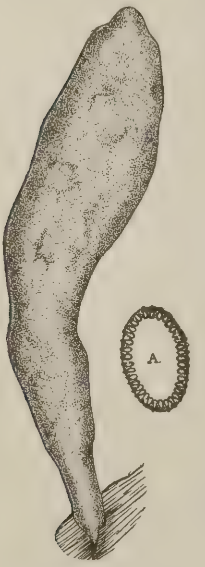

Fig. 2254.—*Xylaria polymorpha*, showing the Plant Natural Size, and a Section at *A* of the Stroma showing the Perithecia around the Margin.

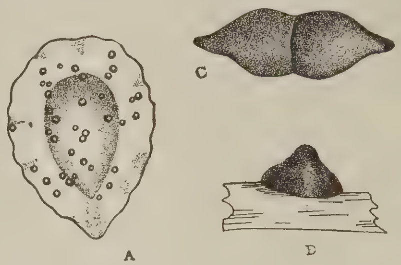

Fig. 2255.—*Caryospora putaminum*, one of the Sphæriales. *A*, Inside of a peach pit showing the scattered perithecia, natural size; *B*, a single perithecium viewed from the side; and *C*, a single spore which is apparently two-celled but has two additional minute cells at the apices.

4. Sphæriales.—This is the largest order of the Ascomycetes, and eighteen families represented by over sixteen hundred species have been described from the United States. Many of them are small or even microscopic in size, and only a few are in any way conspicuous; of the latter, one stromatic form is quite common growing in clusters about old stumps and known as *Xylaria polymorpha*, from its woody character (Fig. 2254). Another form is common on old peach pits that have remained out of doors over winter; this has discrete perithecia as shown in Fig. 2258, *A*. Still another type has long-beaked perithecia (Fig. 2251). The plants of this and three other small orders have formerly been known under the name of Pyrenomycetes and our species have been treated by Ellis and Everhart.† The species of the Sordariaceæ

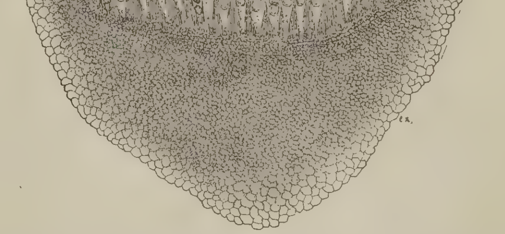

Fig. 2256.—*Lasiobolus equinus*, One of the Cup Fungi (Pezizales). Section through the entire plant, showing the asci in position mixed with the sterile paraphyses. (After Durand.)

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* Salmon: "A Monograph of the Erysiphaceæ." Illustrated with nine plates. Memoirs Torrey Club, vol. ix.

† Ellis and Everhart: "The North American Pyrenomycetes," 1892.

have been made the subject of a recent study by Griffiths,* and this group furnishes a most valuable introduction to the study of the Ascomycetes in general and especially to the methods of cultivation in moist chambers.

5. TUBERALES.—The members of this order are all subterranean in their habits and include the edible truffle looked upon as one of the dainties of the epicure. The true truffle is found in Southern Europe, where either dogs or pigs are trained to dig them. They vary in size from an acorn to that of one's fist and have a warty appearance on the exterior. They are best when fresh, but are most commonly sold in a canned form. Two moderate-sized truffles sell in the market for about three francs (sixty cents). Various reports are current regarding their occurrence in this country, but so far the true edible truffle has not been reported. A large number of subterranean fungi have been found in California where they have been studied by the late Dr. Harkness, and if truffles are ever found in America they are more likely to occur either in California or in the Southwest where the climatic conditions more closely resemble those of Southern Europe.

6. PEZIZALES.—The cup-fungi form an extensive group which has been comparatively little studied in this country. They vary all the way from the size of a pinhead or even smaller to several inches across, some of the larger fleshy ones being used for food. They all bear the asci in a more or less concave layer in the bottom of the cup (Fig. 2256) and are normally closed above when young, but become concave, plane, or even convex as they mature. Some are stalked as shown in Fig. 2257, but the greater part are either very short-stalked or sessile.

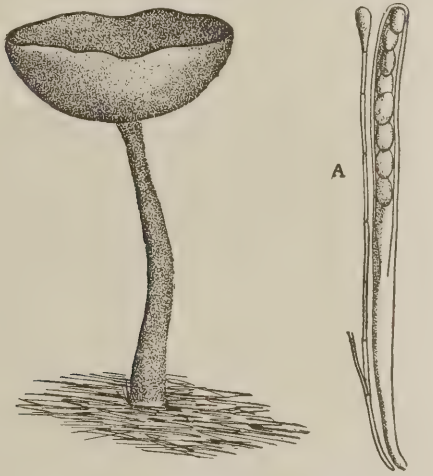

FIG. 2257.—*Peziza macropus*, One of the Cup Fungi (Pezizales), showing an Ascus with Spores and One of the Paraphyses at *A*. (After Lindau.)

7. HELVELLALES.—This, the highest order of the Ascomycetes, contains the largest species of any order and consequently those that are most likely to be concerned with the mycophagist. Two prominent types are represented by two families, which differ technically in the method of discharging their spores; the first include club-like or capitate forms, few of which are of sufficient size to furnish much of a meal though the gelatinous *Leotia* is sometimes eaten. *Mitrula phalloides* (Fig. 2258) is a fairly typical form of this family; in this species the ascospores are confined to the enlarged portion of the club. The other family, known as the Helvellaceæ, contains the morels, the gyromitras, and the helvellas, of which the first is by far the best-known group in this country, being quite widely known as the spring mushroom or in some places as *the* mushroom, it being the one most commonly used for food in certain regions. There are several species of which the most common as well as the best known is *Morchella esculenta* (Fig. 2259). All the morels are edible and delicious articles of food; in Europe they are very commonly dried for winter use and sparingly used as a delicate flavor for soups. The only plant that by any possible chance would be mistaken for them is the *Phallus* or stink-horn fungus, but no one possessed of the sense of smell would possibly mistake that for an edible species. The morel has a hollow stem, hence the plants should be carefully split and cleansed inside before eating as they are likely to contain snails and other animals which also regard them as a delicacy. In cooking, the flavor is improved by parboiling them and rejecting the original water in which they are boiled.

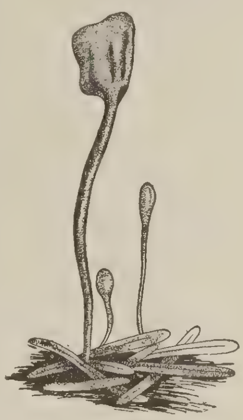

FIG. 2258.—*Mitrula phalloides*, one of the Helvellales, Natural size.

Gyromitra is a much larger fungus; *G. brunnea* has a chocolate-brown convoluted pileus and a white stem an inch or two thick; the whole plant is often five to seven inches high, and single specimens have been found that weigh as much as fourteen ounces; it has been found only in the Ohio valley region. A second species is *Gyromitra esculenta* and is a much smaller plant with a wider distribution, though it is by no means as common in America as in Europe; it is two to three inches high with a strongly convoluted brown pileus, which ranges from

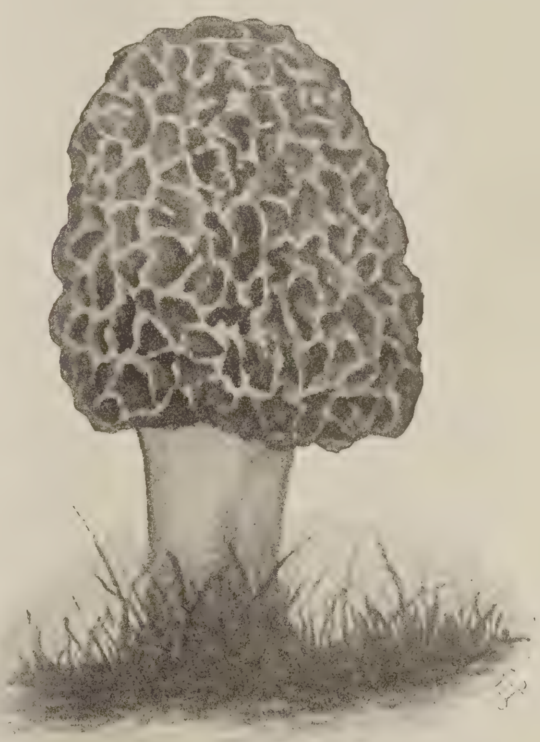

FIG. 2259.—*Morchella esculenta*, the Morel or Spring Mushroom. (Helvellales.) (Natural size.)

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* Griffiths: "The Sordariaceæ of North America." Illustrated with nineteen plates. Memoirs Torrey Club, vol. xi., part i., 1901.

chestnut brown to blackish according to the age or state of maturity. In Europe it is regarded as a great delicacy and is often preserved in cans for winter use. It contains a greater or less amount of helvellic acid, particularly when old, and this is a highly poisonous substance; it is soluble in hot water and can be removed by boiling and rejecting the water, but the plant should never be eaten when past its prime—a remark that may well apply to all mushrooms. The symptoms of poisoning are similar to those described for phallin below and there is no known antidote for the poison.

Besides the true Ascomycetes there are a series of forms that are analogous to conidial stages of some of the forms of the Ascomycetes. Some of these are undoubtedly conidial stages of some known or unknown species of ascus-bearing fungi for which the true relations have not yet been ascertained; some may represent forms that have lost all except their conidial stage of reproduction; while on the other hand there are doubtless a number of forms provisionally placed here from some superficial resemblance that really are perfect forms in themselves. They are known as *fungi imperfecti*, and form plant diseases known as leaf spots, anthracnose, blights, and leaf wilts.

The literature bearing on the subject of the parasitic diseases of plants is very extensive, but very widely scattered in the reports and bulletins of the various state and national agricultural experiment stations. Dr. Sturgis, of New Haven, has made an elaborate index of this literature arranged by host plants.*

CLASS III.—BASIDIOMYCETES (*The Basidial-spore Fungi*).

This group is a somewhat heterogeneous one, but contains species of fungi that produce their spores on basidia (Fig. 2242). The group includes four types of fungi as follows: (1) The lower Basidiomycetes consisting of parasitic rusts and smuts; (2) The tremellines or jelly fungi. These are represented by three orders of which the jew's ear, a dark-colored fungus used as food by the Chinese, is all that need be mentioned; (3) The Hymenomycetes, which contain the ordinary mushrooms and toadstools; and (4) The Gastromycetes, containing the puff-ball and their allies representing five distinct orders.

THE SMUTS AND RUSTS.

The smuts (order USTILAGINALES) are more or less familiar from their attacks on corn and the ordinary cereals, all of which are affected by one or more species. The chlamydospores of the fungus, which form the greasy black powder seen in the corn smut or in the smutted heads of grain, germinate with the grain and produce basidiospores, which germinate directly and produce a widespreading mycelium which grows parallel with the growth of the host plant and ultimately matures its spores.

The rust fungi (UREDINALES) are likewise parasites affecting the higher plants and many of them form destructive diseases. They are peculiar in their methods of reproduction in that some species have three distinct methods, developing three sorts of spores; others have two methods in which two different series may be represented; others may have only one method, and it may be any one of the three sorts of reproduction known among these plants. Where two or three methods of reproduction are known, the case is often complicated by one of them occurring on a different host plant from the others. The ordinary wheat rust is the common type which presents as complicated an example as possible.

THE HYMENOMYCETES.

After passing over the three orders of the tremellines or gelatinous fungi we come to the ordinary toadstools and mushrooms which, in accord with modern terminology, form the order AGARICALES. Of these there are three families that contain fleshy species, and these can be easily distinguished by the nature of the spore-bearing surface which appears underneath the pileus; those bearing lamellæ belong to the agaric family (Agaricaceæ); those with pores or tubes to the Polyporaceæ; and those with spines or teeth to the Hydnaceæ; a fourth family also containing fleshy species is devoid of a pileus, but consists of club-like or coral-like fungi often greatly branched and dividing; these are the Clavariaceæ; there is still another family but it is not of importance in the present consideration.

1. AGARICACEÆ.—In the ordinary pileate mushrooms the spore-bearing surface is spread over a series of radiating lamellæ underneath the cap or pileus; on this surface the spores are borne on basidia and at maturity drop and are scattered by the wind; these spores are of different colors in various species, and this fact has been made use of in distinguishing the various genera. The young plant has the pileus commonly closed something after the manner of an umbrella, and the stem is then short so that the whole mushroom at an early stage is massed into the form of a ball. In certain species the whole plant is enveloped in a more or less membranous covering known as the *volva* (Fig. 2261, *C*); as the mushroom expands this volva is ruptured and it is either carried up on the top of the pileus in the form of separable scales or it remains at the base in the form of a cup; this is by far the most important portion of the mushroom as it is the one by which the most dangerous fungi are detected. It is absolutely necessary to have the complete base of the stem certainly to distinguish between edible and poisonous forms. An additional structure to be noted is the *veil*, which in the young form extends from the margin of the pileus to the stem as a complete covering, but which normally breaks away from the margin of the pileus and forms a more or less definite ring (*annulus*), which may be narrow and ring-like or hang down in the form of a skirt. In one genus the veil separates from the stem and hangs in a fringe around the margin of the young pileus; in at least two genera the veil is very slight though clearly marked in young forms but entirely disappears in the older plant so as to appear to be entirely wanting. While it is comparatively easy for one familiar with mushrooms clearly to distinguish the ordinary genera at sight as easily as the maples, oaks, or pines are distinguished among trees, it is more difficult for a novice to distinguish them even with keys at hand for separating them. The following synopsis of the genera containing edible or poisonous species may be helpful in attaining this end.

SYNOPSIS OF THE GENERA OF AGARICS CONTAINING EDIBLE AND POISONOUS SPECIES

- Stem central.
  - Juice milky, white or colored .... LACTARIUS.
  - Juice not milky.
    - Spores white.
      - With a volva and annulus both................ AMANITA.
      - With a volva but no annulus......... .... AMANITOPSIS.
      - Volva wanting but annulus present.
        - Lamellæ free from the stem; pileus normally scaly .... LEPIOTA.
        - Lamellæ united with the stem .... ARMILLARIA.
      - Both volva and annulus wanting.
        - Lamellæ thin with acute edges.
          - Lamellæ free; plant reviving after drying. MARASMIUS.
          - Lamellæ decurrent; stem fleshy........... CLITOCYBE.
          - Lamellæ adnate; plant brittle; stem fleshy; pileus usually bright colored .... RUSSULA.
          - Lamellæ sinuate; stem fleshy............. TRICHOLOMA.
        - Lamellæ in the form of shallow folds with obtuse edges; plant yellow.................. CANTHARELLUS.
    - Spores pink or salmon-colored; with neither volva nor annulus.
      - Lamellæ free from the stem .... PLUTEUS.
      - Lamellæ decurrent on the fleshy stem .... CLITOPILUS.
    - Spores rusty brown; annulus arachnoid disappearing when mature; lamellæ adnate......... CORTINARIUS.
    - Spores dark brown or black.
      - Pileus melting to a black inky fluid when mature COPRINUS.
      - Pileus not melting; spores dark brown.
        - Veil remaining as an annulus; lamellæ free. AGARICUS.
        - Veil remaining as a fringe on the margin of the pileus; evanescent when old.......... HYPHOLOMA.
- Stem lateral or wanting; spores white or lilac-tinted. PLEUROTUS.

Some of the above terms will require some illustration and the following figures will be useful; the lamellæ may be *free* (Fig. 2260, *F*), or variously attached to the stem, in which case they may be *adnate* (Fig. 2260, *A*), *sinuate*, or notched near the stem (Fig. 2260, *S*) or *decurrent* as in Fig. 2260, *D* and in Figs. 2262, 2263.

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* Report Connecticut Experiment Station, 1897, 182–222.

(*White-spored Series.*)

Amanita.—The white-spored agarics with both veil and volva contain all the most deadly fungi and their characters should be carefully noted. Fig. 2261 gives a characteristic illustration of *Amanita phalloides* which is the more dangerous because it superficially resembles some of the edible species. Its volva and veil have already been noted; it should be observed, however, that in some species of *Amanita* the volva in mature forms may not form a distinct cup at the base at shown in the figure, but may exist in the form of a straggling fringe of teeth at that point, the greater part having been carried up in the form of floccose scales at the top of the pileus. We have quite a number of species besides the four enumerated below, and though some of them are edible the best advice that can be given the amateur is to learn to distinguish the genus *Amanita* and then let it entirely alone.

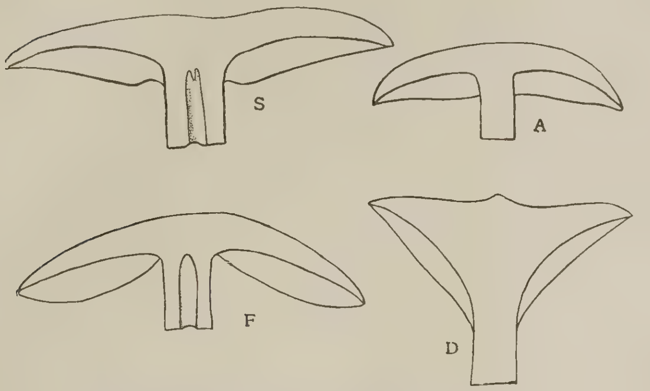

FIG. 2260.—Methods of Attachment of the Lamellæ of Agarics to the Pileus and Stem, shown in Sections. *A*, Adnate lamellæ; *D*, decurrent lamellæ; *F*, free lamellæ; and *S*, sinuate lamellæ. In *F* and *S* the stems are hollow.

The two most poisonous species are the fly-agaric (*Amanita muscaria*) and the poison cup (*Amanita phalloides*). *Amanita muscaria* has a yellowish pileus varying from yellowish-white to yellow orange* and has a white stem, white lamellæ, and white veil. The volva appears at the base of the bulbous stem only in the form of scales, the greater part of it being carried up in the form of loose floccose scales at the top of the pileus. The poison it contains is known as muscarin, which has a very unpleasant taste; symptoms of poisoning from it occur in from a half an hour to two hours after eating. (For an account of the actions, symptoms, and treatment, see *Poisoning*).†

Amanita phalloides is still more dangerous because it contains phallin for which there is no known antidote. The species varies in color, being pure white, yellowish, greenish-olive, or umber in its different forms; the pileus is usually viscid or slimy when moist and in age is often free from any of the remnants of the volva; the lamellæ, stem, and veil are all white; the volva is subject to the greatest amount of variation of any portion, sometimes being largely carried up to the top of the pileus and sometimes remaining more prominently as a cup at the base. It has been something of a question as to whether these variations do not indicate more than one species, but the fact remains that all of them are deadly poisonous. The phallin that they contain is regarded as an albuminous poison and acts directly on the blood corpuscles. There is no unpleasant taste in the fungus to warn the patient, and preliminary symptoms do not commence until from nine to fourteen hours after the poisonous mushrooms are eaten.* Besides these two poisonous species there is one edible species that should be mentioned, since its use as an article of food is historic as well as extensive. In Italy where it has been very extensively used since the time of the Romans, hundreds of bushels are brought into the markets of the cities during its season, and it is equally common in our Southern States, being found rarely as far north as Massachusetts. This is known as Cæsar's mushroom (*Amanita cæsarea*) and is most nearly related in appearance to the fly agaric. It can, however, be readily distinguished by the following marks: the pileus is usually a deep orange yellow, rarely appearing lighter colored; the stem, veil, and gills are all a clear yellow color; the volva appears in the form of a firm cup at the base of the stem and is white, fragments being rarely carried up on the pileus as is so common in the fly agaric. It is often very large, sometimes expanding to ten inches or more across the pileus, though it occurs in much smaller forms.

Amanitopsis.—This genus differs from *Amanita* in having no veil or annulus, and agrees with it in the possession of a volva. *A. vaginata* is very common in some portions of the country and is regarded as a delicacy; it has a thin usually grayish pileus, which is distinctly striate on the margin; the stem and lamellæ are white. .

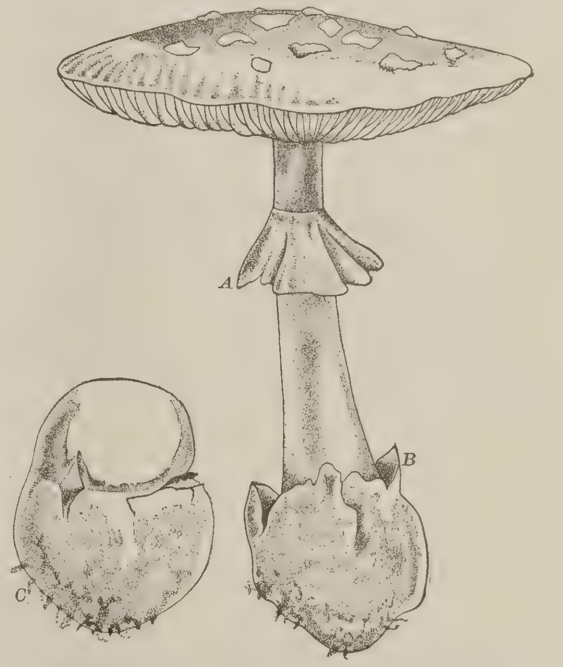

FIG. 2261.—*Amanita phalloides*, the most Poisonous Mushroom. One-half natural size. *A*, Annulus; *B*, volva; *C*, young plant enveloped in volva.

Lepiota.—The species of *Lepiota* are known as parasols and for the most part are edible species. The only exception known is seen in the anomalous *L. Morgani* which differs from all other agarics in the possession of green spores; it is very common in various parts of the Ohio valley and southward and has occasioned severe illness from being used as food; others have partaken of it with no ill effects, but it should be classed as doubtful. *Lepiota procera* is common in the Northern States and can be distinguished by its brownish or reddish-brown pileus, three to five inches across, and its very long hollow stem frequently reaching ten inches in length and bulbous at the base. *L. naucinoides* is a white species with a slightly bulbous base; it is likely to be confused with species of *Amanita* which it resembles closely except that it has no volva; as *Amanita phalloides* sometimes grows in cultivated fields where *Lepiota naucinoides* occurs, the danger becomes all the greater of confusing the two species. There are numerous other species of *Lepiota*, but none of them need consideration here.

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* In European works this species is figured a bright red, but I have never seen it this color in America.

† Illustrations of the fly-agaric may be consulted as follows: Michael: "Führer für Pilzfreunde," No. 55; Marshall: "Mushroom Book," pl. 1; Gibson: "Edible Toadstools and Mushrooms," pl. 4; Atkinson: "Studies," Figs. 52–54; McIlvaine, "1,000 Amer. Fungi," pl. 9; Cooke: "Illust. British Fungi," pl. 117: Fries: "Sverig. atl. Svampar," pl. 1; Gillet: "Champ. de France," pl. 8.

* Illustrations of the poison-cup may be consulted as follows: Michael: "Führer für Pilzfreunde," No. 58; Gibson: "Edible Toadstools and Mushrooms," pl. 13; Atkinson: "Studies," figs. 55–57; McIlvaine: "1,000 Amer. Fungi," pl. 6, figs. 2 and 3; Cooke: "Illust. British Fungi," pl. 2; Bulliard: "Flore de la France," pl. 2; Gillet: "Champ. de France," pl. 3.

Armillaria.—Only one species of this group needs attention here. It is a gregarious species growing about old stumps, the pileus ranging from whitish to reddish-brown, though brownish-yellow is the more common tint. The lamellæ are white at first but become reddish with age. It is sometimes eaten though is not considered very palatable. It is of most importance as a destructive agent of growing timber, as its widely spreading mycelium penetrates the heart wood of trees at some distance from where the mushroom appears above ground and produces decay to the height of several feet.

Marasmius.—To this genus belongs the fairy ring champignon often seen in lawns and pastures, forming circles or part circles often many feet in diameter. The genus differs from the ordinary fleshy agarics in having a persistent pileus which revives after desiccation and produces a new crop of spores. The pileus is an inch to an inch and a half in diameter.

Clitocybe.—To this genus belong several diverse species, all agreeing, however, in having a fleshy stem and decurrent lamellæ. *Clitocybe illudens* is a large golden-yellow species, often produced in clusters of fifty or a hundred at the base of old stumps. It is a gorgeous species, but has a bad reputation as an article of diet, though it is not known to be poisonous. A smaller species (*Clitocybe laccata*) is sometimes eaten. The general characters of the genus can be seen in the two illustrations (Figs. 2261 and 2262).

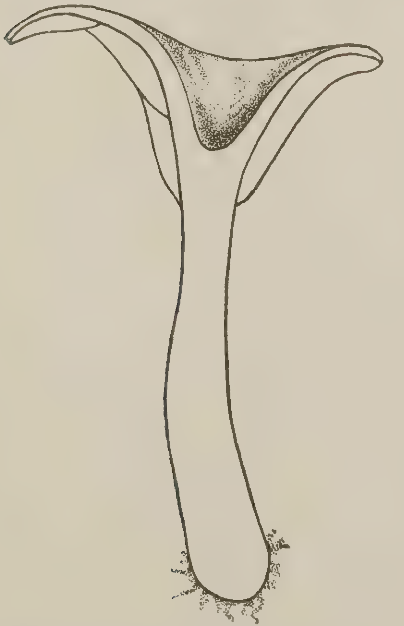

Fig. 2262.—*Clitocybe cyathiformis*, One of the Agarics, showing Infundibuliform Pileus and Decurrent Heterophyllous Lamellæ. (After Cooke.)

Russula.—The species of *Russula* are not well known but are comparatively numerous and common and conspicuous features of every forest and shaded path from their bright colored red or green pilei. Several of the species, among them the poisonous *Russula emetica*, have a strong acrid taste when raw, and the members of the genus unsuitable for food may be distinguished by tasting them in a raw condition. The acrid ones have a peppery taste. *R. emetica*, as its name indicates, produces nausea and from its peppery taste is not likely to be confused with edible species; *Russula virescens* with pale apple-green pileus is often eaten. While bright colors like red and green predominate in the genus, some are white and others clay-colored and brown.

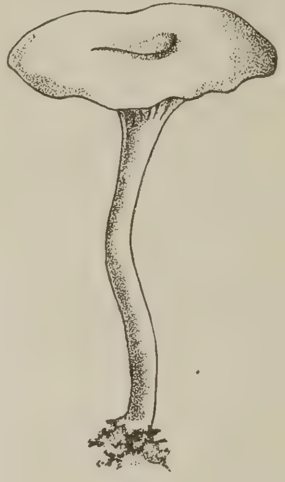

Fig. 2263.—*Clitocybe fragrans*, One of the Agarics, showing Umbilicate Pileus and Decurrent Lamellæ. (After Cooke.)

Lactarius.—The milky fungi are closely allied to Russula structurally, but differ in yielding a milky fluid when bruised or cut. They are often peppery to the taste, and the commonest white species is called *Lactarius piperatus* from this circumstance. By this means the objectionable species can be detected, though even *L. piperatus* is sometimes eaten as its peppery taste is said to be removed in cooking. *L. volemus* is a species with white milk and a reddish-brown pileus and stem; *L. deliciosus* differs from all others in having orange-red milk; as its specific name would indicate, it is a delicate article of diet. We have some forty species in this genus.

Tricholoma.—Only one of the many species of this genus need be considered here; this is *T. personatum*, whose spores are often dirty white instead of pure white as in most of the genus; the whole plant is a pale violet lilac color, and this color is usually constant in the younger conditions of the plant; it is very common late in the season in waste grounds and dumping places. *Tricholoma sulfureum* with a dry yellow pileus is about the only suspicious member of the genus, though even that is not known to be poisonous.

Pleurotus.—The so-called oyster mushrooms are readily distinguished by their lateral habit, either having no stem at all or being attached by a very short lateral stem; none of the species are injurious and many of them have a delicate flavor; *P. sapidus* with violet-tinted spores is the most abundant, and there are several other quite closely allied species.

Cantharellus.—This genus contains the chantarelle or Eierpilz of the Germans, much used for food in Europe where it is more common than with us. *C. cibarius* is the common species of an egg-yellow color. *C. floccosus* is a larger species of a lighter yellow color and forms funnels four to six inches high.

(*Pink-spored Series.*)

Pleuteus cervinus is one of the most abundant species of its group, growing always on decaying logs and characterized by its mouse-colored pileus, its lamellæ separate from the stem and its pink spores. It is reputed edible.

Clitopilus differs from this genus in its decurrent lamellæ; the sweetbread fungus (*C. orcella*) and the allied *C. prunulus* are the only species that are likely to be met and neither is very common.

(*Rusty-spored Series.*)

Cortinarius is a very extensive genus, its species usually appearing in woods from late in the summer to November. They are all terrestrial, by which character the genus is distinguished from its rusty-spored neighbors; when young the species have a cobwebby veil which disappears with age. One of the commonest is the violet

Cortinarius, which has a deep violet color throughout, except the mature lamellæ which become rusty brown from the ripening spores. Our numerous species are not so well known as those of many other genera; none of the species, however, are reputed poisonous.

(*Brown- or Black-spored Series.*)

Agaricus contains the common field mushroom (*A. campestris*) and quite a number of allied species. While this species is generally well known it may be well to add its diagnostic marks: 1. It has no volva whatever at the base of the stem. 2. The lamellæ are pink when young but gradually change to brown or blackish-brown as the spores mature. 3. The lamellæ are free from the fleshy stem, and when young are covered with a veil which later forms a distinct ring around the stem. 4. The stem is stuffed, or filled with a somewhat softer substance. This is the mushroom commonly cultivated from spawn, and immense quantities of mushrooms inferior to those that can be grown in this country are canned in France and imported to this country. It is said that mushrooms may be grown at a profit to retail at twenty five cents a pound, but the price in New York is sometimes six or eight times that amount.*

Hypholoma.—One of our commonest late fall mushrooms is the brick-top often growing in large masses at the base of stumps. Professor Peck distinguished several species, using taste as a guide in separating species. *H. sublateritium* is commonly reputed poisonous in Europe, but many of the closely allied species have a delicate flavor. Specimens used for food should be individually tasted before cooking and those with a bitter taste should be rejected.

Coprinus.—The species of this genus are among the most abundant of the wild mushrooms and three species are common in lawns and waste places. The genus can be very readily recognized by the fact that the pileus melts speedily to an inky fluid when mature, and it has taken the popular name of ink-cap from this circumstance. *C. micaceus* is a small species that grows in prodigious quantities about old stumps, often appearing very early in the spring; it has a thin pileus of a pale buff or yellowish color and narrow lamellæ. *C. atramentarius* grows in clusters often of many individuals; it has a grayish-brown moist pileus and very wide crowded lamellæ; *C. comatus*, popularly called the shaggy mane, is cylindrical in shape and has a shaggy pileus formed of yellowish-brown scales on a white foundation. It is more common in the autumn, usually growing in waste grounds.

In recent years the subject of edible mushrooms has become considerable of a fad in this country and several works of greater or less value have appeared treating the subject in a more or less popular manner. Among the best of these are Miss Marshall's "Mushroom Book," Gibson's "Edible Toadstools and Mushrooms," and Atkinson's "Studies of American Fungi," while McIlvaine has published a more aspiring work under the title "One Thousand American Fungi." All are extensively illustrated, the first and third named with many reproductions of photographs. The best general work on the subject of edible species, however, is Michael, "Führer für Pilzfreunde." The text is in German, but the principal edible and poisonous species, most of which are common to Europe and America, are illustrated with excellent colored plates.

The nutritious character of mushrooms has been greatly overstated in many works of a popular nature. The nitrogen supposed to be the nutrient element in mushrooms is found to belong in part to proteid substances of low food value, and a portion is found in substances that are indigestible and hence not available for food. The mushrooms are to be regarded as a delicacy rather than as a staple article of food, and their nutrient value, instead of being comparable to meats as was formerly supposed, is rather to be compared with succulent vegetables. Their cultivation and study, however, are worthy of much greater attention than they have been given heretofore in this country.*

2. POLYPORACEÆ.—Certain of the fleshy species of bracket fungi, such as are seen growing on old tree trunks, are edible. Among these *P. sulfureus* with bright-yellow pores and dainty pinkish-yellow pileus is best known; it is a large species often growing in large overlapping masses which are conspicuous from their brilliant color.

P. frondosus, a brownish species with extensive compound branches, is also said to be edible. Most of the bracket fungi, however, are curious and ornamental merely as they are of a woody consistence; the two mentioned above indeed are useful for food only when very young. It is said that the substance of *Polyporus officinalis* has been used as a substitute for quinine, but its properties have never been thoroughly investigated. The beefsteak fungus (*Fistulina hepatica*) grows as a fleshy tongue-like mass from chestnut trees and can be easily recognized by its fibrous beef-like consistency and its tubes whose mouths are entirely separate from each other. It has much the same appearance as real beefsteak and is cooked in the same way.

Most of the fleshy spore-bearing fungi, however, belong to the genus *Boletus*, of which we have many common species. Some of them have a bitter taste like the common *B. felleus* and should be rejected; one entire section of the genus has tubes whose mouths are a lurid red, a totally different color from the rest of the tube; these are regarded as poisonous and are to be carefully avoided; other members of the genus change the color of the flesh to a bright blue when wounded and exposed to the air. This is particularly true of a species which in one of our popular works on mushrooms has been figured under an incorrect and misleading name †; it has a reddish pileus and the flesh instantly changes on exposure to injury. It is a dangerous species, the more so because it has been figured as an edible one.

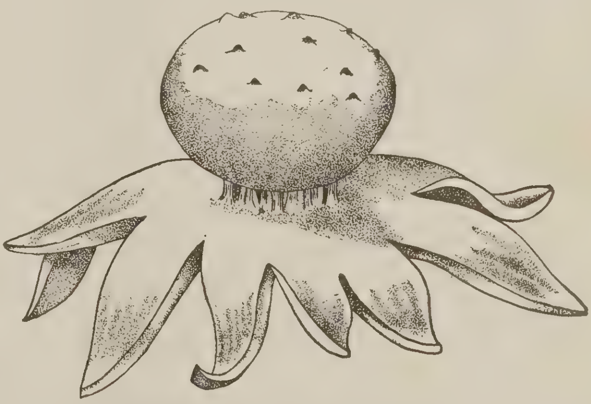

FIG. 2264.—*Myriostoma coliforme*, a Rare Member of the Puff Ball Family (Lycoperdales).

Many of the *Boleti* are edible, but the species are difficult to distinguish by a description; like most fungi they have distinctive characters by which they may certainly be known when seen and the safest guide is some one already familiar with the species. Once learned in this way the species of mushrooms are as easily distinguished as the ordinary fruits or vegetables.

3. HYDNACEÆ.—Two types of edible toothed fungi are found. One consists of white coral-like masses in

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* There are numerous works bearing on mushroom culture, but the following are as good as any: Falconer: "Mushrooms; how to Grow Them," 1896, and Robinson: "Mushroom Culture; Its Extension and Improvement," 1870. The Department of Agriculture at Washington has also issued a free bulletin on the subject.

* Concerning the nutrient value one can profitably consult Dr. Mendel's results of chemical analysis in American Journal of Physiology, I: 225–238, 1898.

† Palmer's: "Mushrooms" as *Boletus subtomentosus*; its true name is *B. miniato-olivaceus*.

which *the teeth all point downward* when growing; all the species are found on tree trunks. They are easily recognized by their teeth, and the three common species, *Hydnum coralloides*, *H. erinaceus*, and *H. caput-ursi* are all equally edible.

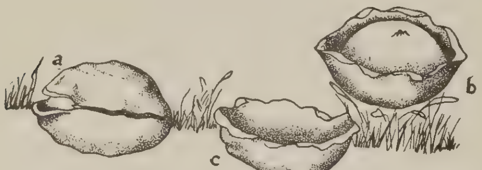

FIG. 2265.—*Catastoma circumscissum*, One of the Lycoperdales. Natural size. *a*, Shows the outer peridium rupturing at the equator; *b*, shows the upper part removed and overturned with the inner peridium rupturing with a single crater at a point originally at its base; and *c*, shows the lower half of the outer peridium left as a cup in the earth after the removal of *b*. (After Morgan.)

Two pileate species are also edible; *H. repandum* with yellowish or whitish-yellow pileus and teeth very brittle, and *H. imbricatum*, brown with overlapping scales on the pileus and grayish teeth.

4. CLAVARIACEÆ.—The club-fungi growing in the form of coral-like masses *with the branches pointing upward in growth* contain several edible species. None of them are dangerous, and they form a good subject for experimentation as they are often abundant in moist woods.

It will be readily seen from the above sketch that no hard and sharp rules can be given that will distinguish edible species of mushrooms from poisonous. Like the higher plants there are good, bad, and indifferent species, and the separate species can best be learned as good or bad by intimate acquaintance with them, the same as we have become able to distinguish apples from pears and carrots from radishes by learning each one separately.

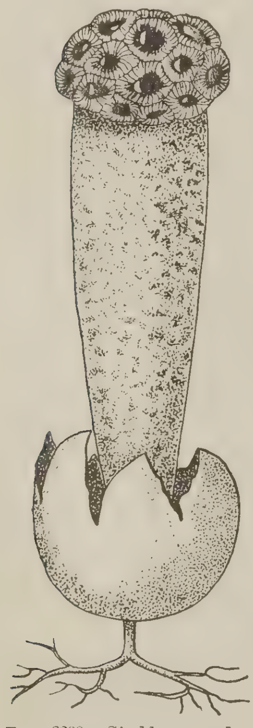

FIG. 2266.—*Simblum rubescens*, One of the Phalloids. In life the stem is reddish; in the early stage the entire plant is enclosed in the cup-like base, then in the form of an egg. (After Gerard.)

THE GASTEROMYCETES.

The last group of fungi are represented by the puff balls and their allies that in some respects represent some of the highest developments among the fungi. It is scarcely necessary to call attention to the peculiarities of the various orders and families, but attention can be called to a few typical forms, since some of them are abundant and excellent articles of food. Among these is the giant puff ball (*Calvatia Bovista*), which sometimes reaches a prodigious size and often is large enough to furnish a meal for several people. Smaller species ranging from three to six inches in diameter are *Calvatia cyathiformis* and *Calvatia craniiformis*. In the former the mature spores are purplish, in the latter they are olive brown. It is only when the flesh of the puff-ball is pure white and much the consistence of cottage cheese that it is suitable for food, and any indication of darkening, caused by the ripening of the spores, should cause the plant to be rejected.

A smaller fungus is commonly seen in *Bovista plumbea*, which is only an inch or so in diameter, but is considered a delicacy in some places. The numerous smaller species of *Lycoperdon* are likewise edible, but are usually too small to be considered available for food. Allied to the puff balls are the curious earth-stars of which no less than three genera are represented in America. Fig. 2264 represents the least common form. *Geaster*, more common, differs mainly in being attached to the outer peridium at one point and opening by a single crater.

Another puff ball with the curious habit of overturning and opening at the bottom of the inner peridium is seen in *Catastoma*, whose life history was first studied by Morgan (Fig. 2265).

The stink-horns belong to an order (Phallales) distinct from the puff balls (Lycoperdales). These well-known members of the group are reputed poisonous and all doubtless contain phallin as one of their constituents. They form underground in the shape of an egg, and this bursting allows the rapid distention of the stem by means of which the spore mass is carried up where flies may be attracted to it and aid in their dispersion. Three of the larger species are more or less common throughout the country, and there are several curious forms less widely known, one of which is represented in Fig. 2266.*

Lucien M. Underwood.

FURUNCLE. See *Boil.*

GAINESVILLE (GA.) MINERAL SPRINGS. — The town of Gainesville is located in Hall County on a small tableland 1,300 feet above the sea-level, and lies between the headwaters of the Oconee River, which flows into the Atlantic, and those of the Chattahoochee, which finds its way to the Gulf. The Alleghanies, stretching around the place to the north and west, form a natural bulwark which breaks the force of the northern winds of winter. The town thus enjoys a dry, bracing climate, without extremes of either heat or cold. Daily observations made for the United States Signal Service during the period of ten years showed a mean winter temperature of 44° F. and a mean summer temperature of 71° F. The health tables of the United States census show a lower death rate in this portion of Georgia than in any other section of the country. White, in his "Statistics of Georgia," makes the statement that no case of consumption was ever known to originate in Hall County. In close proximity to the thriving and rapidly growing little city are numerous mineral springs, some of which have come into use as health resorts. We have thought it advisable to consider these springs in the following group:

Gower Springs form one of the chief attractions of the city. They are located just beyond the corporate limits, and are connected with the city by a street-car line. These springs are chalybeate in character, the iron being held in solution by carbonic acid, which makes it readily assimilable. The following qualitative analysis was made some years ago by Prof. W. J. Land, of Atlanta:

Free carbonic acid.
Hydrosulphuric acid.
Iron carbonate.
Manganese carbonate.
Iron apocrenate.
Potassium sulphate.
Sodium sulphate.
Iron crenate.
Lithium phosphate.
Calcium sulphate.
Magnesium sulphate.
Potassium bromide.
Oxygen gas.
Nitrogen gas.

An excellent hotel is maintained at the Springs, and we are informed that an increased number of visitors come to the resort every year. The waters are recommended in general debility, digestive disorders, and kidney affections.

The *Deal Spring*, located two miles from the city, wells up in a basin of solid rock, and is said to possess excellent properties in the treatment of indigestion and dyspepsia and in the dentition period of children.

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* The present illustrations are reproduced from a series used to illustrate an introductory work on fungi, by the author of this article, "Moulds, Mildews, and Mushrooms," New York, Henry Holt & Co.

The *New Holland Springs* are also within two miles of Gainesville, on the Southern Railroad, which has a station at the Springs. The improvements consist of a hotel and cottages for two hundred guests. The situation is in a beautiful and extensive grove of native oaks, and the Springs furnish about two hundred gallons of water per minute. The water is recommended for indigestion and general debility, but we are unable to present a complete analysis in verification of its claims. An old qualitative examination showed the presence of the following ingredients:

Calcium carbonate.
Magnesium carbonate.
Potassium carbonate.
Iron, probably combined with carbonic acid.
Sodium chloride.
Carbonic acid gas.

James K. Crook.

GALACTAGOGUES.—(Gr. *γάλα*, milk, and *ἄγειν*, to lead.) The secretion of milk is normally associated with pregnancy, but may occur in pseudocyesis, and in ovarian and uterine tumors. It is often seen during the first week of life, in both male and female children. The secretion of milk may be established and maintained by the application of a nursing child to the breast of a woman who is not at the time and never has been pregnant. In one case a child eight years old nursed her mother's infant for some months, and in another a woman, fifty-nine years old, ten years after the cessation of menstruation, nursed a child for some time.

The length of time during which the milk may continue to be secreted varies from nine to sixteen months, but in rare cases this period may be prolonged for as long a time as five years, if the child be allowed to nurse.

The causes of defective lactation are various in character. Thus, for example, there may be some mechanical interference with the escape of the milk, as when the lactiferous tubes and acini are not developed, or the epithelial cells are imperfect, or a previous injury or disease has caused total destruction of the glandular tissue. These conditions are not amenable to treatment. On the other hand, when there is simply a lack of development, or the gland and nipple have received some trifling injury, the condition should be investigated and treated before the end of gestation. The breast of every pregnant woman should be examined by her physician three or four months before the expected confinement, and if the breasts are found to be small and poorly developed and the nipples fissured or depressed, appropriate treatment should be instituted. If the nipples are hard, the application of some bland aseptic oil or ointment—*e.g.*, lanolin and boric acid—will be found useful as a means of softening them. The breast should be massaged, and at the same time the nipples should be drawn out by grasping them between the thumb and finger, while with the other hand the breast is stroked toward the nipple. This should be done daily for five or ten minutes at a time. The adoption of these measures will enable the child, when placed at the breast—which should be done as soon after labor as the mother's strength will permit—to grasp the nipple effectively. After this first attempt at nursing, the child should be placed at each breast, alternately, every four hours. Should the child be unable to grasp the nipple, the latter should be drawn out with the breast pump or a clay pipe, and, if this does not prove sufficient, a glass nipple shield, with rubber nipple, should be employed. The sucking of the child is the best stimulus to the flow of milk, and should always be obtained if possible; but, if the child cannot be made to nurse, then suction will have to be made with the breast pump for five or ten minutes every four hours. The breast at the birth of the child contains colostrum, and at the end of from thirty-six to sixty hours ripe milk. During the first period the child should be nursed every four hours, but afterward, on the appearance of ripe milk, it should be nursed every two hours.

Another cause of defective lactation is a plethoric state of the body, a condition which readily responds to treatment. The diet should be carefully regulated, milk being made one of its chief constituents, and all stimulants should be avoided. The extract of thyroid gland should also be prescribed in five-grain doses. Under this plan of treatment, combined with the occasional administration of a dose of castor oil, the obstruction to the flow of milk should soon disappear. In these cases the use of the thyroid gland extract not only increases the flow of milk, but at the same time improves its nutritive quality.

Torpor of the mammæ is another cause of inactivity of their secretory apparatus, and when this is the case great benefit may be derived from the application of electricity. Both poles having been moistened, the positive one is placed deep in the axilla or on the back, while the negative one is applied gently over the nipple. The current employed should be no stronger than is agreeable to the patient, and this mode of applying it should be continued for about two minutes. Afterward, the negative pole should be glided along the sides of the breast, in a stroking fashion, for another two minutes. Then, finally, the poles should be applied to the sides of the breast for the same length of time. Electricity may be applied in this manner once a day for a period of four or five days; and usually it will be found that a single such séance will fill the breasts after the milk has disappeared for some days.

Among the other local therapeutic methods which have been used with varying success may be mentioned the application of warm poultices made of a weak mixture of mustard (not strong enough to burn) or of calabar bean, or of the leaves of the castor-oil plant. Gentle massage alone will often suffice to start the flow, or we may combine with it inunction of olive oil or of castor oil. Repeated applications of the breast pump and enveloping the breast with warm cloths are also very efficient methods.

The internal administration of drugs, for their galactagogue action, has not proved very satisfactory. Jaborandi will, it is true, increase the flow of milk, but its action is only temporary and cannot be depended upon when a prolonged effect is needed. It is best given in the form of the fluid extract of pilocarpus, in half-drachm doses; this preparation being less nauseating than the jaborandi itself. Or the effects of the drug may be obtained from hypodermatic injections of pilocarpine hydrochlorate, in gr. $\frac{1}{12}$ doses.

Physostigmine increases temporarily the flow of milk. So also do the preparations of ammonia—the carbonate and the acetate—when given in moderately large and continued doses. The alcoholic stimulants, such as ale, porter, and beer, and the malt preparations possess the power of increasing the quantity of milk secreted, but the quality is thereby deteriorated. To such a degree is this true that they should rarely be used except in small quantities. The volatile oils, especially the oil of anise, impart a pleasant flavor to the milk, and in consequence the child will be likely to draw much better. In this indirect manner they may serve to increase the flow of milk.

The most usual cause of defective lactation is anæmia. It is a well-known fact that the functional activity of an organ is directly proportional to the supply of blood furnished to that organ, and this is a very important law to remember when we are dealing with such a gland as the mammary. We may therefore expect to secure the greatest improvement in the secretion of milk from the taking of those substances and the adoption of those hygienic measures which tend to increase the supply of blood and to improve its nutritious qualities. The mother should be in the best possible condition before and after the arrival of the child, and this result should be secured by the administration of tonics, such as iron, arsenic, nux vomica, and quinine, and by the patient's taking proper food and exercise. The diet suitable for a nursing mother should be nutritious and easily digested. For the first few days of the puerperal period the mother should have milk, animal teas and broths, eggs, gruel, soups of beans and peas, and small amounts of tea, cocoa, or coffee, with toast and crackers. It is well to avoid the limited diet of tea and toast which so many women take at this time. Later on in this period and during that of lactation, the mother should have an abundant supply of water, soups, meats, milk, eggs, and vegetables. Of the latter turnips, carrots, beets, potatoes, spinach, asparagus, and lettuce will aid in the formation of milk. The mothers of the working class will be found to give milk in larger quantity and of a better quality than do those who live under higher social conditions. This is due to their simple mode of living and to their outdoor life.

Systematic exercise in the open air should be taken as soon after confinement as the mother's condition will permit, for by this means the proteids will be diminished in amount and the fat increased, thus creating a milk which is easily digested by the child.

The mother should at the same time avoid those drugs which decrease the milk supply, namely, belladonna, when taken in large amounts or used locally, and saline and hydragogue purgatives; for the removal of large amounts of fluid from the body will greatly diminish the supply of milk. It is also desirable to prevent, as far as possible, any nervous shock or worriment, for the effect upon the mother is likely to be such that her milk will be rendered unfit for the child.

The proper care of the breast during lactation is important. The nipple and breast should be washed with a saturated solution of boric acid both before and after nursing, and these parts should be kept covered with soft sterile lint or gauze held in place by a breast binder which gives support and ease to the breast. If this course is adopted there will be fewer cracked nipples and abscesses of the breast. In cases in which fever occurs during lactation it is often possible to retain the secretion of milk for three or four weeks, if the breasts are gently massaged and emptied three or four times a day with the breast pump. Then, when the temperature returns to normal, the child may again be put to the breast. In those cases in which there has been an abscess of the breast in early infancy, or during a former lactation, the danger of the formation of a fresh abscess is only slightly greater than it is in a perfectly normal breast. If care is taken to keep the parts thoroughly clean, and if they are not allowed to become engorged, we may rightly expect that such a breast will furnish a sufficient supply of good milk. *Stricker Coles.*

GALANGA; GALANGAL.—Lesser Galangal. The rhizome of *Alpinia officinarum* Hance (fam. *Zingiberaceæ*), a perennial herb of flag-like habit and the floral peculiarities of ginger and cardamom plants. It is an inhabitant of Hainan and other parts of Southern China, where it is also cultivated as an article of commerce. Galanga has been long known in Europe, as well as in Asia, and was formerly esteemed as a domestic spice or flavor.

The dried rhizome is cylindrical, often branched, about as large as the little finger, and in pieces two or three inches in length. The nodes are close together and very prominent, as slender annulations. Texture hard, tough; color deep brown; odor aromatic, curcuma-like; taste pungent. It contains an *essential oil* to which its odor is due, and probably some pungent resin. The oil is reddish-yellow, with the odor of cajeput and the taste of camphor. It has a specific gravity of 0.921, and contains cineol. Its qualities as a medicine are essentially those of ginger. As a medicine galanga is obsolete in Europe, and nearly so as a spice, although it is said to be used with other things in flavoring cordials, in veterinary mixtures, etc. *Henry H. Rusby.*

GALBANUM.—"A gum-resin obtained from *Ferula galbaniflua* Boiss. et Buhse (fam. *Umbelliferæ*), and probably from other species" of *Ferula* (B. P.; no longer official in the United States). It is not certain whether the product of the "other species" always comes separately, as it certainly sometimes does, or whether the drug is sometimes a mixed product. The plants are huge perennial herbs of Persia and the adjacent region.

The galbanum exists, like other gum resins, in the plant as a fragrant creamy latex, and exudes spontaneously from the crown and stem, or flows upon puncture, in white drops that soon become thick and sticky, and finally hard and brittle, by the action of the air. As they dry, they also turn to a light yellow-brown or buff color. These drops or tears, collected when nearly dry and not sticking together, compose the "Galbanum in tears"; when collected in a softer state, and running more or less completely into a granular or even homogeneous mass, they are the more common "galbanum in mass." The pharmacopœial description was as follows: "In tears from the size of a pin's head to that of a pea, and larger; mostly agglutinated, forming a more or less hard mass; externally yellowish, or pale brown; internally milk-white, bluish-white, or yellowish, with a waxy lustre; odor peculiar, balsamic; taste bitter and acrid. When moistened with alcohol, galbanum acquires a purple color on the addition of a little hydrochloric acid."

Like other substances of its class, galbanum makes a yellowish emulsion with water, and contains a varying amount of *essential oil* (six per cent., more or less) according to its freshness and softness. It consists, besides, of about three-fourths *resin* and one-fourth *gum*, excluding a variable amount of coarse impurities. The oil is a colorless, pleasant-smelling hydrocarbon of the turpentine type. It is an article of commerce, and described by Schimmel as having a normal specific gravity of 0.930, boiling between 165° and 300° C., and containing *cadinene*. The resin is a yellowish-white amorphous substance, soluble in alcohol, and remarkable for yielding by dry distillation a brilliant *blue*, rather thick *essential oil* (see German Chamomile for similar substance), and the crystalline substance called *Umbelliferon*, which, in its turn, melted with potash, yields the derivative *resorcin*.

Galbanum was used by the ancient Hebrews as an ingredient of some incenses. Along with other gum resins it has had, in its day, some reputation as an emmenagogue and antispasmodic, and it is still occasionally given with these qualities in view. Somewhat more often it is administered in chronic bronchitis or laryngitis as an expectorant. Rarely it is given in rheumatism, with probably no benefit. The principal present employment of this antiquated medicine is as an ingredient of stimulating plasters.

It should be heated and strained, to separate dirt and refuse, before employment in pharmacy. 1 gm. (gr. x.–xx.) may be considered a full dose, and can be administered in pill form or as an emulsion.

Henry H. Rusby.

GALBRAITH SPRINGS.—Hawkins County, Tennessee.

Post-Office.—Galbraith Springs. Hotel and cottages.

Access.—Viâ Southern Railroad (formerly East Tennessee, Virginia, and Georgia) to Russellville, Hamblen County, thence 9 miles north by private conveyance to Springs.

For the last half-century these Springs have been known and resorted to by the inhabitants of the surrounding districts. In *ante-bellum* days they were frequented by hundreds, who made their temporary abodes in pole cabins around the Springs. The location is in a broken, mountainous country, 1,400 feet above the sea-level. The immediate surroundings of the Springs are uniquely charming in their wealth of vale and wood, brooks, rivulets, and waterfalls, and other features to please the fancy. The situation of the Springs is one mile distant from the Holston River, in a romantic glen, 330 feet above the base of Short Mountain. A path leads to the United States Signal Station on the top of Short Mountain, which is 1,320 feet above the Springs and 2,702 feet above the sea-level. From this point one of the most extended and charming views to be found among the mountains of East Tennessee is revealed to the eye. The hotel is a very comfortable establishment, where the visitor will soon learn that all the needful arrangements for his comfort and diversion are at hand. Among the amusements at Galbraith Springs may be mentioned bowling, dancing, and music. Hunting and fishing may also be indulged in. The springs are four in number. An analysis was made in 1884 by Prof. W. A. Noyes, of the University of Tennessee, with the following results:

LIGHT CALCIC-CHALYBEATE.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Calcium carbonate	3.84
Calcium sulphate	.92
Calcium nitrate	Trace.
Calcium phosphate	Trace.
Magnesium carbonate	.47
Lithium carbonate	Trace.
Sodium sulphate	.26
Sodium chloride	.07
Potassium sulphate	.16
Iron carbonate	.41
Alumina	.03
Silica	.68
Total	6.84

Temperature of water, 55° F.

This analysis shows a very light mineralization, yet the water seems to possess considerable merit as a ferruginous tonic, and can be taken in large quantities. It is also an excellent table water. *James K. Crook.*

GALLACETOPHENONE. — $C_6H_2,CH_3CO,(OH)_3$. A derivative of pyrogallol, $C_6H_3(OH)_3$, one atom of H being replaced by an acetyl group. It is a pale-yellow, crystalline powder, almost insoluble in cold water, very soluble in hot water, alcohol, ether, and glycerin.

It was introduced as a substitute for pyrogallol (Rekowski: *Therap. Monat.*, September, 1891), the advantage claimed for it being its freedom from toxic and irritating action. Pyrogallic acid and its derivatives owe their therapeutic properties to their reducing action which is usually too rapid and causes an excessive irritation. Gallacetophenone possesses this reducing action in a lesser degree than the others, although sufficiently strong to prove an efficient antiseptic. A further advantage is that it does not discolor the skin, the hair, or the linen with which it comes in contact. It also is devoid of any irritating or toxic action.

It was recommended for the treatment of skin diseases, particularly for psoriasis. In this condition its beneficent effects were said to be manifested in twelve hours, the patches becoming paler and thinner, and disappearing after ten or twelve days.

This drug has not been much employed. Dr. Herman Soldenburg (New York *Medical Journal*, February 6th, 1892) reports his success with it in several cases of long duration. It is employed in the form of a solution or in that of an ointment, the strength in either case being ten per cent. *Beaumont Small.*

GALLANOL—gallic acid anilid, gallanilid [$C_6H_5.NH.CO.C_6H_2(OH)_3$]—is obtained by boiling together tannic acid and anilin. It occurs in colorless crystals or gray micaceous scales, slightly soluble in cold water, soluble in boiling water, alcohol, and ether, and insoluble in benzol. It is bitter and astringent. Having found this tannin compound free from the undesirable properties of pyrogallol and chrysophanic acid, yet as effective in treatment, Cazeneuve and Rollet introduced it in 1893 as a remedy in psoriasis, chronic eczema, and other skin diseases. For eczema it is employed in ointment of three to twenty per cent. strength, or with talcum as a dusting powder. For favus, ringworm, psoriasis, or prurigo it is used in twenty-per-cent.-solution in alcohol with a little ammonia. Before this remedy is applied, the skin should always be cleansed with an alkaline soap solution. *W. A. Bastedo.*

GALL BLADDER AND GALL DUCTS, DISEASES OF.—(*Krankheiten der Gallenwege; Maladies des voies biliaires.*)

I. CATARRHAL INFLAMMATION OF THE GALL BLADDER AND GALL DUCTS.—(*Catarrhal jaundice; Icterus simplex; Icterus catarrhalis; Icterus gastro-duodenalis; Catarrh der Gallenwege; Inflammation des voies biliaires.*) Since the investigations of Wyss, Charcot, Legg, and others, a broader significance has been given to catarrh of the bile ducts than formerly; and at the present time pathologists are wont to include in the term all forms of jaundice save that due to stenosis and non-inflammatory occlusion of the ducts (by foreign bodies, growths, external pressure, etc.), or to a narrowing occurring as a sequence of a previous inflammation—catarrhal, suppurative, or exudative (see the section on Stenosis, etc., farther on). For a full discussion of these questions, see *Icterus;* suffice it to say that to a catarrh of the finer bile ducts has been attributed the jaundice of acute yellow atrophy of the liver, of phosphorus and other forms of poisoning, and of the various fevers, thus narrowing the limits of hæmatogenous jaundice. This section will be devoted only to an account of catarrhal inflammation of the bile ducts in the common acceptation of the term.

ETIOLOGY.—A predisposition to catarrh of the bile ducts is said to exist in persons of a bilious temperament. Persons liable to catarrh of other mucous membranes are prone to this affection. It arises very frequently from an extension of catarrhal inflammation from the stomach and duodenum, and the causes which excite the latter condition are prominent in the etiology of the former. Hence an attack may occur as the result of exposure to cold and dampness, of checking of the perspiration, of errors in diet, of over-eating, and of the ingestion of rich or fatty food, and of acrid substances, as well as of certain drugs and stimulants. A debauch is often followed by an attack, and the inhalation of noxious vapors and foul gases has been known to excite the disease. The so-called "epidemic" jaundice is thought to be due to a poison introduced from without through the food, drink, or air. Some epidemics, however, have the characteristics of an acute infectious disease and are attended with considerable mortality. Mennert's report of the Saxony epidemic of 1889 includes 518 cases, of which 73 per cent. were in children. There were 30 deaths. Weil's disease (infective jaundice) has been considered by some to be a modified typhoid infection. Several cases of typhoid fever with marked jaundice at the onset have been reported by Ogilvie (*British Medical Journal*, January 12th, 1901), and their resemblance to this disease noted. The Widal reaction should be of great value in this regard. Dalgleish[1] speaks of an extensive epidemic of catarrhal jaundice, at Bloomfontein, which bore a strange relation to the prevalent typhoid and dysentery. Whole families might be attacked, but more frequently it was seen that one or two of a household might have jaundice while the others would be affected with typhoid or dysentery. The disease in most instances ran an afebrile course, was attended with marked gastric symptoms, and was not of as long duration as simple catarrhal jaundice. The possibility of this epidemic being a modified typhoid infection has not escaped notice.

An extensive epidemic occurred in Michigan during the summer and fall of 1897. Six hundred and seventy-five cases were observed, mostly in children. The affection was commonly more severe in adults. Whole families were attacked. Usually after a few days of indisposition, slight fever, gastro-intestinal disturbances, and jaundice, more or less marked, would appear, the symptoms then abating. Jaundice in this epidemic was always of short duration. The liver was rarely enlarged.[2]

In addition to the causes which set up the catarrh of the bile ducts, either coincidently with, or secondarily to, the gastro-duodenal catarrh, there are other local causal conditions existing in disturbances of the portal circulation. Obstructive cardiac disease and impeded pulmonary circulation from lung disease or feeble heart lead to portal congestion, and hence to a venous stasis and consequent catarrh of the mucous membranes. Tumors in the abdominal cavity, enlarged glands, or the enlargement of any of the organs, by interfering with the portal circulation, may set up a catarrh. Dutton Steele reports a case of jaundice apparently due to kinking and obstruction of the bile duct from extreme gastro- and entero-ptosis.

Catarrhal inflammation of the bile ducts, with or without gastro-duodenal catarrh, is frequently caused by malaria, by syphilis (in the secondary stage), and by gout (Murchison). Acute phosphorus-poisoning and lead-poisoning are often attended with gastro-hepatic catarrh. The jaundice that accompanies cholera, typhus, typhoid, pneumonia, pyæmia, septicæmia, and other fevers, is due to a catarrh of the bile ducts.

Direct irritation of the mucous membrane of the ducts by mechanical causes, as by the passage of gall stones or by the presence of parasites, frequently causes a catarrh which may be local or diffused. Finally, it is said that pathological states of the bile itself irritate and excite inflammation of the ducts. In persons who are starving, from choice or necessity, it is said that the bile, which is retained in the gall bladder, becomes acrid and sets up an active inflammation. The jaundice that in rare cases accompanies cirrhosis, amyloid and fatty liver, is due to a catarrh of the ducts.

The season of the year is believed to have some influence on the production of biliary catarrh,—spring and autumn being the favorable periods; hence the terms icterus vernalis, autumnalis, etc. Sex exercises no influence on the frequency (Ewald, von Schüppel); yet, in our cases, excluding "epidemic" jaundice, the males were largely in preponderance. The disease is most frequently seen in the early period of life, and after forty a jaundice is not likely to be due to primary catarrh, although a case of one of the writers was seventy years of age. Firemen, puddlers, stokers, and laborers who are exposed to extremes of temperature are liable to the affection.

Morbid Anatomy.—In the milder forms post-mortem inspection reveals nothing, for, as we often find in a laryngitis so severe as to cause stenosis, the congestion and œdema subside after death. In the more severe varieties, redness, swelling, succulence, and often ecchymosis of the mucous membrane, are observed. The lumen of the ducts, if not occluded by the flaccid lining membrane, is filled with proliferated epithelium and mucus. The latter may be bile-stained, especially at first, or may be clear and viscid. A plug of firm mucus often stops the orifice. The papilla stands out prominently on the duodenal mucous membrane and is red and softened, but a probe readily penetrates the duct, and bile may be forced out by pressure of the hand on the gall bladder, although the feeble "vis à tergo" of the biliary secretion during life is not sufficient to overcome the obstruction. The duct, beyond the seat of the catarrh, is stained with bile. In the more advanced or prolonged cases the ducts are completely blocked by a somewhat firm, gray mucus, intermingled with proliferated epithelium and leucocytes. The congestion is more intense, ecchymoses are more common, and a more marked thickening of the mucous membrane is observed, due to cellular infiltration. Now it is that denudation of the epithelial surface takes place, ulcerations develop, and the terminal ducts undergo inflammation and dilatation from retention of, and irritation caused by, the imprisoned bile. Anatomically, catarrhal inflammation of the ducts may be divided into an acute form of ten days' duration (no lesions after death, or only congestion and œdema), a subacute form, lasting from two to six weeks (with the above lesions, cell proliferation and mucus formation in abundance), and a chronic form, continuing from two to six or eight months (excessive catarrh, abrasion, ulceration, dilatation, stricture, and retention abscesses or cysts). Catarrhal inflammation results either in the return of the parts to a normal condition, or in a stricture of the ducts (see the section on Stenosis of the Ducts, farther on) and its sequences, or in a "biliary" or "hypertrophic" cirrhosis of the liver.[3] Dropsy of the gall bladder occurs also as a sequence of catarrh of the cystic or common duct, with occlusion.

The seat of the catarrhal inflammation may be limited to the finer ducts, to the common duct, or to the cystic duct and gall bladder. Thudichum (1863) describes a catarrhal inflammation of the finer ducts in which perfect biliary casts are formed. Meckel regards such casts as frequently forming the nuclei of gall stones and has given the name of "lithiatic catarrh" to the condition. Robson suggests the term "desquamating angio-cholitis." The *pars intestinalis* was formerly considered to be the only portion of the common duct involved in catarrhal icterus. If the finer ducts are the seat of catarrh, as in phosphorus-poisoning, the larger ducts are pale and covered with a film of mucus or a small amount of thin bile. If the gall bladder be the exclusive seat, its mucous membrane undergoes changes similar to that of the duct; its contents are a dark-colored inspissated bile, and mucus in abundance, or a thin, watery mucus or muco-pus fills the bladder. According to Mayo Robson, catarrhal cholecystitis, or chronic catarrh of the gall bladder, without jaundice, forms a distinct and definite disease frequently mistaken for cholelithiasis and only recognizable at operation, when nothing but thick, ropy mucus is found in the bladder or ducts. This mucus, often in the form of sago-like plugs, gives rise, in its passage, to the gall-stone-like attacks. In these, as a rule, medical treatment is sufficient, but in persistent attacks, in which no gall stones are passed in the fæces, no jaundice develops and no tenderness is present in the gall-bladder region, the operation of opening and draining the gall bladder is urged. Robson reports the cure of several cases by this procedure.

The histological changes in the parenchyma of the liver vary. Either the appearances of a liver long stained with bile are found, or the atrophic and degenerative alterations seen in stenosis of the ducts are observed, or a "biliary" cirrhosis develops (consult these sections).

Symptoms, Course, and Duration.—These depend upon the cause; if this be one that is readily removed or that passes off quickly, the symptoms are mild and the duration is brief, as in the catarrh that succeeds the passage of a gall stone. If the affection arise from obstructive heart or lung diseases, the symptoms are mild, but the duration is long. The catarrh that accompanies malarial disease or a gastro-duodenitis is the most severe and protracted. The mode of onset also varies with the cause. The gastro-duodeno-hepatic form is usually preceded by gastric symptoms for three or four days; while that due to other causes follows the usual manifestations of that cause.

The description which follows is that of a catarrhal inflammation of the ducts supervening upon duodenal catarrh, which may be regarded as a type of the disease under consideration.

The affection may begin in any of several different ways:

The gastro-duodenal symptoms may precede the hepatic by three or four days; or the first observed symptom may be jaundice; or the attack may be ushered in by a chill, followed by fever with gastric symptoms and, in a few days, by jaundice. Loss of appetite, a tongue covered with a heavy yellow fur, pasty and bitter buccal secretions, and an offensive breath, are prominent. Nausea in the mornings, or at the sight of food, and vomiting of a glairy mucus, or, early in the attack, of a bitter, bile-stained, acrid fluid, may occur. At the same time there are epigastric distress, weight and fulness, some tenderness on pressure, soreness, or even marked pain. Later, there are pain and tenderness in the right hypochondrium and over the liver. It is denied by some authorities that the liver and gall bladder are enlarged, but I have observed enlargement of the former constantly in chronic cases. The abdomen is usually distended with gas, and eructations of gas and the imperfect products of digestion occur. The bowels are constipated, or a diarrhœa from indigestion may occur in the early stage. In a few days jaundice appears; first the conjunctiva, then the face, and in a short time the entire body is discolored. The icterus varies in extent and degree. The conjunctiva alone may be affected, and it may be merely of a faint yellow tinge, or, in chronic cases, of a deep bronze. The fever, which is from 100° to 103° F., generally subsides with the advent of the jaundice, but it may continue for ten days or two weeks as a simple continued fever, the so-called "gastric" or catarrhal fever. The well-known symptoms and effects of obstructive jaundice are present (see article on *Icterus*).

It is important, however, to remark the uniform persistence of the jaundice. Probably the most characteristic symptom is the slow pulse, which often distinguishes this form from other varieties of jaundice. Fagge calls particular attention to this symptom. Headache is present often in the beginning, with or without vertigo. After the jaundice becomes developed, the usual nervous symptoms of the disease are manifested.

If the case be a mild one, the gastric symptoms first subside, and then the jaundice gradually disappears, without any serious disturbances of nutrition. In the more protracted cases, however, anæmia, emaciation, and prostration are marked, the degree depending on the duration of the disease.

The mild idiopathic cases continue for from ten days to three weeks, the more severe ones for from six to ten weeks, and the more obstinate cases as long as five or six months.

Should stricture of the duct take place as a sequence of the catarrh, and should suppuration of the ducts occur, and abscesses form, fever of an irregular type, often with chills, and with exhaustive sweats, will usually be present. A similar fever, or one of an intermitting character, also accompanies the development of secondary cirrhosis. In these instances the liver and gall bladder are enlarged.

Inflammation of the gall bladder alone is characterized by pain and tenderness in the right hypochondrium, by enlargement of the gall bladder, and by slight fever, with, at times, nausea. Jaundice may not be present, but in many cases a gall stone in the gall bladder or cystic duct may give rise to jaundice from an inflammatory occlusion of the common bile ducts by extension. Riedel is quoted by Gumprecht[4] as stating that two-fifths of the cases of jaundice in cholelithiasis arise in this way (Mayo Robson).

Diagnosis.—The presence of one of the causes or antecedent pathological conditions just noted, the early age and previous good health of the patient, the sudden and uniform development and persistence of the jaundice, and the absence of the physical signs of organic disease of the liver, clearly indicate simple catarrhal icterus. Care must be taken not to confound it with the jaundice of acute yellow atrophy, and it must not be forgotten that, in apparently the most simple jaundice, grave cerebral and other symptoms due to acute atrophy may arise. Acute yellow atrophy may occur at an early age in the pregnant female; the more marked epigastric pain, the jaundice of the upper portion of the body, the vomiting of blood, the cerebral symptoms, and the alterations in the size of the liver and spleen serve to distinguish it.

The jaundice due to obstruction by gall stones develops quickly, is quite marked, and varies in its intensity from time to time; paroxysmal and persistent pain is more pronounced than in the simple form; the patient is usually a female, and the attacks occur late in life. The diagnosis must be made between jaundice from simple obstruction and that caused by pressure on the ducts. The physical signs and clinical history of the many forms of external pressure must be considered (see section on Stenosis, etc.). Pain, fever, sweats, increase in size and tenderness of the liver and gall bladder, with prostration and emaciation, occurring late in the disease, indicate stricture and the formation of abscesses, or purulent inflammation of the ducts. If the jaundice continues longer than two months, if the pulse is frequent from the first, if sweats are marked, if emaciation rapidly ensues, and if the patient is over thirty years of age, it is more than possible that some affection other than simple catarrh, and not revealed by physical signs, is present. An important observation in this connection is, that frequently in malignant disease of the liver or bile ducts, jaundice due merely to an associated catarrh may disappear under treatment, the disease meanwhile persisting and progressing. The jaundice due to pressure or obstruction will be little, if at all, influenced by any means (Mayo Robson). It has occurred to the writers that the existence of a diarrhœa in the course of catarrh of the bile ducts would indicate closure at the orifice; for then the pancreatic duct would likewise be occluded, and diarrhœa, a well-known symptom of pancreatic disease, would ensue. The presence of fat and blood in the stools would also point to this conclusion.

Prognosis.—This is usually favorable, but depends more or less on the cause. Gastro-hepatic catarrh terminates favorably. The presence of symptoms indicating purulent inflammation of the duct renders the prognosis grave. Prolonged jaundice, with the advent of marked cerebral symptoms, is very serious. The possibility of the development of icterus gravis should not be forgotten. We are inclined to think that the prognosis is seriously modified by inactivity of the kidneys, and that cerebral symptoms are not so liable to occur if the renal secretion is abundant. Hemorrhage, in any of its forms, is of bad omen.

Treatment.—The line of treatment to be adopted depends entirely on the cause of the catarrhal inflammation. If it arise from cold and exposure and is seen early, a warm bath or a vapor bath, and the use of saline cathartics, or of small doses of tartar emetic, are of service. Full doses of quinine and Dover's powder at bed-time, with a light purge in the morning, will often relieve the general symptoms of "cold," and exert a favorable influence upon the local catarrh. If the cause of the disease is a coexisting gastro-duodenal catarrh, a mechanical emetic, repeated twice on each of the first two days, is often of service. Large draughts of hot water, either at bed-time or repeated throughout the day, are grateful and beneficial. They are made more palatable by the addition of some one of the alkaline citrates. At the same time an alkaline purgative, largely diluted, should be employed, and then gastric sedatives or the mineral acids. Patients with catarrhal jaundice rarely apply for treatment until some time after the jaundice has appeared, and as this is generally due to a gastro-intestinal catarrh, a system of treatment that has usually been successful in these cases may here be presented. First, in the acute form: a mercurial purgative is first administered. We usually prescribe from one-twelfth to one-third of a grain of calomel, in combination with from three to ten grains of bicarbonate of soda every two hours, until eight or twelve powders are taken. If the bowels are not acted on freely by this combination, it should be followed by a saline laxative. At the same time light sinapisms are applied to the epigastrium. After the bowels are freely opened, it will often be found that the tongue has already become somewhat cleaner, and the bad taste, the nausea, and the vomiting have been relieved. If this happy effect has been produced, a weak acid or an alkali and bitter may be used. On the other hand, if the symptoms are not relieved, and the tongue is clean, denuded of epithelium or pointed, and red at the tip, a sedative is indicated. In the more chronic cases in which the gastro-duodenal catarrh has subsided, we have other conditions to deal with, and the indications are to remove the obstructing mucus and reduce the inflammation and thickening of the ducts. These indications may be met by remedies that in a measure increase the secretion of bile and thereby drive away the obstruction, or by drugs that render the mucus less viscid and that relieve the congestion. Among the remedies of this latter class the alkalies are of great service, and may be given in the form of the alkaline effervescing waters, as the Carlsbad, Vichy, or Hathorn waters, or the salts of ammonium, sodium, or potassium may be used. Bartholow advocates the phosphate of sodium in drachm doses; Guiteras, iodide of potassium in small doses freely diluted, and taken fasting. The muriate of ammonium is one of the most reliable alkalies; it may be given in ten- or twenty-grain doses, three or four times daily, combined with an equal quantity of powdered licorice, and dissolved in water. Ipecacuanha has been advocated in small doses, as one-half of a grain or one grain, frequently repeated, for the same purpose.

To increase the secretion, nitro-hydrochloric acid, the vegetable hepatic stimulants, benzoate and salicylate of soda, and alkaline waters are of service. The alkalies should be taken in a large amount of water, preferably hot, on an empty stomach, and by slowly sipping the fluid. Emetics are also used for their mechanical effect, but care must be observed lest their too free use incite a fresh catarrh or aggravate the one already existing.

Mosler and afterward Krull have successfully treated catarrhal jaundice with enemata of cold water. They inject, once in twenty-four hours, from one to four pints of cold water (59° F.) slowly into the rectum, and require the patient to retain it as long as possible. With each injection the temperature of the water is gradually raised, otherwise it will not be retained.

By pressure on the fundus of the gall bladder, if it be readily grasped, directing the force toward the vertebral column, Gerhardt has succeeded in overcoming the obstruction and relieving the jaundice. The same author recommends the application of electricity. A strong induced current with slow interruptions is used; one electrode is placed over the gall bladder, the other on the back at a point directly opposite, and close to the spinal column. No doubt Kussmaul's treatment of intestinal obstruction, by washing out the stomach, would be of service in this affection.

The diet should be bland and non-irritating. Fats, sugars, and, as a rule, starches, should be excluded, as well as spirituous or malt liquors. Light broths, beef-tea, milk, and later, meats, fish, eggs, and oysters should be the chief articles of diet. Afterward tomatoes, lettuce, spinach, celery, and the like may be used.

The troublesome, and at times serious, effects of the jaundice will be treated of under that heading. (See *Icterus.*)

II. PURULENT, ULCERATIVE, AND CROUPOUS INFLAMMATION OF THE GALL BLADDER AND GALL DUCTS (*Cholecystitis et Cholangitis Suppurativa, diphtherica, exulcerans, and crouposa* (Schüppel); *Exsudative Entzündung der Gallenwege* (Frerichs); *Cholécystite et Angéiocholéite*).

Etiology.—According to Bloch, in disease of the gall bladder and bile ducts the bile soon becomes infected with various micro-organisms, principally B. coli communis, staphylococci, and streptococci. Any condition obstructing the flow of bile invites bacterial infection (Charcot et Gombault, *Archives de Phys. et Path.*, 1876; Netter, *Prog. Méd.*, 1886; Terrier, *Revue de Chirurg.*, 1895). Hence foreign bodies, such as gall stones or parasites, in the biliary passages, stenosis and occlusion of the ducts in any part of their course, readily pave the way for any infecting agent.

Fütterer has shown that in a very few minutes after the injection of organisms into the circulation they appear in the bile. Flexner and Chiari have demonstrated the constant presence of typhoid bacilli in the bile in patients dying of typhoid fever, the latter observer describing acute inflammatory lesions in thirteen of nineteen such cases without any gross obstruction in the biliary passages. Camac records an instance of acute cholecystitis with operation in the first few days of an attack of typhoid fever. Cases of acute cholecystitis due to the Bacillus typhosus without previous history of typhoid fever are reported by Cushing and Mitchell. Hunner describes another occurring eighteen years after an attack of typhoid, with operation and isolation of the typhoid bacillus. It can safely be assumed that bacterial infection exists in all cases, and that acute inflammatory infection of the biliary passages may occur without obstruction in many of the acute infectious diseases. Cases of acute phlegmonous cholecystitis and gangrenous cholecystitis are probably only instances of very severe infection, which may spread so rapidly that general peritonitis may occur in a few days. Pratt,[5] in his recent article, shows the frequency of cholecystitis due to the Bacillus typhosus. It therefore seems probable that cholecystitis may begin as a primary local typhoid infection. Pearce[6] has described an instance of the presence of a leptothrix in an acute cholecystitis, the organism being also found in gall stones present in the gall bladder.

Ulcerations of the biliary passage are most frequently due to gall stones. Carcinoma is a common cause, and ulcerations have been met with in typhoid fever and in cholera. The sequelæ of ulcerations, stricture, perforation, fistula, etc., make the condition more serious than it might otherwise be.

Croupous or membranous inflammation of the gall bladder and ducts may occur as the result of irritation from the passage of a gall stone, or it may be a further stage of catarrhal inflammation. Powell (Med. Trans. Coll. Phys., 1829) noted that membranous enteritis was frequently accompanied by gall-stone-like attacks, and it has been suggested that gall-stone colic may be the exciting cause of membranous enteritis. Robson thinks a membranous or croupous formation in the gall bladder or ducts, with passing of the membrane or pieces thereof, accounts for the painful, gall-stone-like attacks. Fenwick (*Br. Med. Jour.*, April 23d, 1891) discovered a true cast of the gall bladder in the fæces twenty-four hours after a very severe attack of hepatic colic. A similar cast had been found two weeks previously under similar conditions. In all suspected gall-stone attacks, in which no stones are found in the fæces, search should also be made for fleshy, tube-like structures or fragments thereof, as they alone may be responsible. Robson is of the opinion that the gall-stone-like attacks seem not infrequently, in subjects of membranous enteritis, to indicate involvement of the biliary passages in a similar condition. Extension of purulent inflammation from adjoining veins or from hepatic abscesses appears to have been the cause in some instances. It is certainly true that a multiform inflammation of the ducts may occur by extension of inflammation from some one localized focus, as an ulceration due to gall stone. This form of biliary inflammation is usually met with in advanced life. Croupous inflammation of the biliary passages is also caused by gall stones.

Morbid Anatomy.—The cases that have been observed by the writers presented nearly all the anatomical appearances that occur in cholangitis and cholecystitis.

There are observed a swollen, thickened mucous membrane, of a pale ashen or slate-gray color; uniform or saccular dilatation of the ducts; and abscesses in the periphery of the duct or along its course. Often a gangrenous appearance of the duct wall is seen. The dilated canals and the abscesses contain yellowish-green bile and pus, sometimes thick and ropy, and often ichorous. The dilatation is most frequently confined to, or most marked in, the left lobe of the liver, and Legg says that the dilated pouches and ducts are lined with columnar epithelium. Ulcers are often found, superficial in character, large and irregular, or quite deep and small. From the healing of the ulcers and the contraction of the cicatrix, the ducts beyond the obstruction are obliterated. This may also occur after exudative inflammation; and in the liver fibrous bands, the remains of the biliary channels, are often seen. The tissue of the liver beyond becomes sclerosed, and the cells proper undergo atrophy and degeneration. The abscesses of the liver may extend into a contiguous vein, or may ulcerate toward the surface; hence a perihepatitis is often seen. Sometimes one large abscess alone is found; rarely do abscesses become encapsulated. The ulcers that have formed are often covered with a gray, gangrenous detritus, which is removed with difficulty. This characterizes the diphtheritic form. In the croupous inflammation of the ducts, fibrin cylinders, well moulded and easily removed, are found. The hepatic structure undergoes some changes: in the mild forms either a connective-tissue overgrowth lights up, or a diffuse hepatitis arises; in the chronic forms with jaundice the liver cells are icteric, compressed into various shapes, and present the appearances of having undergone fatty or granular degeneration.

As a sequence of purulent or exudative inflammation of the gall bladder, marked phenomena are observed. The mucous membrane undergoes the usual changes, the walls become thickened, and the cavity is filled with pus, muco-pus, or pus and bile. Ulcerations, simple or diphtheritic in nature, are formed, and may penetrate to the peritoneal cavity.

Adhesions take place between the gall bladder and neighboring structures, fistulæ develop, and often the adjacent tissues are filled with pus. The ulcers are single or multiform. In mild cases a fibrous thickening of the walls of the gall bladder and its surroundings takes place, followed by contraction and obliteration of the organ. Twice the writers have found the gall bladder firmly contracted around imprisoned gall stones, and in one case numerous sacculi had been formed, each sac containing a gall stone surrounded by bands of fibrous tissue. On the other hand, the gall bladder may undergo extreme dilatation and enlargement, producing an empyema. If the phlegmonous inflammation be confined to the walls, this structure may undergo calcareous degeneration (so-called "ossification").

Symptoms, Course, Duration.—The symptoms are those of the causal condition,—as one of the infective fevers, gall stones, etc.,—combined with the local inflammatory manifestations. Often the condition is not recognized during life, or there may be present only an irregular fever, with rigors. If, after an attack of hepatic colic, fever of an irregular type, chilly sensations, or sharp rigors, occur, and prostration ensues, independently of any paludal affection, we may suspect ulcerative inflammation of the bile ducts. In these cases, the jaundice, which is usually present, deepens, pains in the hepatic region are marked, and a fixed local pain in the right hypochondrium is complained of. If the gall bladder is involved, the physical signs of enlargement of that organ are observed (see the section on Enlargement of the Gall Bladder). As the inflammation proceeds, the symptoms of perihepatitis, local or general peritonitis, occur. In addition to pain in the region of the gall bladder, we have pain and tenderness frequently in the epigastrium. With or without this local inflammation, vomiting is frequent, hemorrhages occur from the stomach and bowel, and often a diarrhœa is started. Budd believed that many cases recovered. If so, the burrowing of the pus must have been in the direction of the stomach or duodenum. An increase of local tenderness, and the presence of tumefaction and redness, show that the direction which the pus is taking is toward the surface. Discharge of the abscess in this position leads to the formation of a cutaneous biliary fistula. If this fortunate termination does not occur, and in a cholangitis it is not to be expected, the fever continues, the gastro-intestinal digestion gives way completely, a typhoid state of the system arises, cholæmia frequently occurs, and finally death. A fatal result may occur from exhaustion, due to the combined influences of the fever, the suppuration, the gastro-intestinal disturbances, and the jaundice; or a peritonitis from perforation or rupture of the gall ducts, or a pylephlebitis, may hasten the fatal termination. Hemorrhages are also liable to occur if the jaundice is of long duration, and they will add to the extreme debility. Cholecystitis, due to foreign bodies or to obstruction of the cystic duct, may run its course, and the contents of the bladder be discharged into the neighboring hollow viscera, or externally, without the supervention of grave general symptoms; local phenomena and physical signs alone indicating its presence. The lodging of a gall stone in a common duct is often and usually associated with a peculiar fever and train of symptoms, the so-called hepatic intermittent fever of Charcot. Osler, Fenger, and Courvoisier describe a ball-valve action of gall stones lodged in the diverticulum of Vater, the bile readily flowing by the stone but becoming easily obstructed and infected under certain circumstances, producing the characteristic ague-like paroxysms which may be frequently repeated (the recurring jaundice deepening with each attack), or may occur at intervals of months or years. Each attack probably represents an infective cholangitis which may quickly subside or may run into the more serious conditions already mentioned as occurring in infection of the biliary passages. Leucocytosis, more or less marked, absence of the malarial parasite in the blood, resistance to quinine, the irregularity of the paroxysms, and the deepening jaundice should distinguish the conditions from malaria. There is usually a history of previous gall-stone colic. Robson states that in his experience several impacted stones were as frequently found as a single stone, freely movable, and acting like a ball-valve.

Diagnosis and Prognosis.—The diagnosis is uncertain, and when the symptoms are latent it is manifestly impossible to make a diagnosis. Pain and swelling of the liver, with tenderness on pressure, irregular chills and fever in a person who is jaundiced, or who has had an attack of gall stones, are strong evidences of exudative inflammation. Cholecystitis may be recognized by local symptoms (see section on Enlargement of the Gall Bladder). The prognosis is very unfavorable on account of the many accidents that may arise.

Treatment.—Stimulants, tonics, quinine, medicines to allay gastro-intestinal irritation and dyspepsia, and morphine or other preparations of opium to relieve pain, are the only means at our command for combating the disease. Unless the disease shows signs of resolution it is now generally advised to open and drain the gall bladder in cases of cholecystitis. In infective and suppurative cholangitis, opening of the gall bladder offers the only chance and is followed in many cases by cure. Terrier (*Revue de Chirurgie*, 1895) and Robson insist upon the value of this proceeding. Removal of stones from the common duct is now performed and is indicated in persisting evidence of obstruction and infection (Halsted).

III. Stenosis and Occlusion of the Gall Ducts.—The canal is occluded when it is completely closed; partial closure, sufficient to cause obstruction, is denominated stenosis. These conditions may be congenital or acquired; the acquired forms alone are treated of in this connection. The causes of each are the same, and the results are similar.

The obstruction may be due to foreign bodies within the duct, to diseases of the duct walls, or to external pressure.

1. The foreign bodies which may find lodgment within the ducts are gall stones, parasites, or, in rare cases—if the orifice of the duct is very patulous, as occurs after the passage of a gall stone,—cherry pits, plum stones, or raisin seeds. The gall stones are generally impacted in the cystic duct, or at the mouth of the common duct. The common round worm has been found in the lumen of the duct. The liver fluke also causes stenosis; but complete obtruction is not effected without the intervention of local inflammatory symptoms. The rupture of an echinococcus sac into the ducts and the discharge of the vesicles cause temporary obstruction. Complete closure is caused by multilocular echinococcus tumors, which cause infiltration, thickening, and ulceration of the wall of the duct. The hepatic and cystic ducts are chiefly involved.

2. The obstruction may be due to chronic catarrhal inflammation, to purulent and ulcerative inflammation, to carcinoma or other morbid growths of the ducts, or to a perihepatitis with thickening of the investing membrane, leading to hypertrophy of the subserous connective tissue and occlusion of the duct. In the inflammatory forms, granulations in apposition coalesce, and the formation of a stricture ensues. When ulceration has previously occurred, the stenosis is due to the contraction of the cicatrix. The causes mentioned in the sec-

tions treating of those affections are the primary causes, therefore, of the stenosis. The lumen of the duct becomes absolutely imperforate in the inflammatory varieties, and the occlusion may extend over a variable length, though it most frequently exists in the common duct. The lumen is not completely occluded in cicatricial stricture, but is impermeable, and is not unlike a urethral stricture. Local or extended thickenings of the duct causing stenosis are due to a connective-tissue hyperplasia, which originates in a previous catarrhal inflammation. The cicatrix of a duodenal ulcer sometimes includes in its grasp the duodenal opening of the common bile duct.

Carcinoma of the biliary passages will be treated of in a separate section. The perihepatitis, which includes in its course the investment membrane of the ducts, is caused by general peritonitis, by right-sided pleurisy, by affections of the liver and adjacent organs, which set up irritation (as, for example, cancer, cirrhosis, ulceration, etc.). As the peritoneal thickening and the new inflammatory tissues grow in age, they contract and thus encroach on the lumen of the ducts. Syphilis is said to be a cause of this local inflammation.

3. External pressure is caused by disease or displacement of contiguous organs. Named in their order of frequency, it is often found that affections of the pancreas, the lymphatic glands in the hepatic fissure, the duodenum, the stomach, the omentum, and the kidney are the sources of pressure. Carcinoma or hypertrophy of the pancreas, carcinoma, tuberculosis, amyloid disease or lymphosarcoma of the lymphatic glands, carcinoma of the stomach, duodenum and omentum, and tumors of the kidney (hydronephrosis or carcinoma) are the essential pathological conditions which lead to the occlusion. Aneurisms of the aorta (Hatton) and of the hepatic artery (Gairdner) cause obstruction. Very rarely tumors of the ovary and uterus, and fæcal tumors, are the cause of occlusion.

The anatomical sequences of occlusion and stenosis of the biliary passages are dilatation of the ducts or gall bladder behind the obstruction, catarrhal or suppurative inflammation of the ducts, enlargement of the liver, at first from the excessive dilatation of the canals, and then from a hypertrophic or biliary cirrhosis, and subsequent atrophy of the liver from pressure of the ducts on the secreting tissue, or destruction of the cells by the connective-tissue overgrowth.

The dilatation of the duct is often extreme. The common and hepatic ducts may be as large as the intestine, and their walls thin, although rupture rarely takes place. The ducts in the liver are also dilated to the size of the finger throughout their extent, even to the surface, causing it to have a vesicular appearance. The walls are not greatly thickened, and are lined with columnar epithelium. The mucous membrane is pale and smooth. The ducts terminate in large pouches, and numerous recesses are seen in the course of the cylindrical canal. Retention cysts are often found. At first the biliary channels are filled with bile only, but after a time this fluid is replaced by a secretion from the glands of the mucous membrane, which is limpid, viscid, and serous in character. The chemical and microscopical examination of the fluid gives no indication of bile constituents. The reaction of the fluid is neutral; it contains albumin. When this fluid is found in the bile ducts, bile is not secreted in them, and the mucous membrane of the ducts is in truth a cyst wall. Whatever bile is secreted is at once absorbed.

The liver is icteric and anæmic; flaccid at first, cirrhotic afterward. The cells undergo atrophy, contain bile pigment and minute oil globules; while cloudy swelling of the protoplasm is observed. The changes peculiar to "hypertrophic" cirrhosis are observed later.

A description of the changes in the gall bladder is reserved for the section on Enlargement of the Gall Bladder.

The *Symptoms* are complex, and include the symptoms of the primary cause and those of biliary obstruction. Aside from the physical signs and symptoms of the causal disease, jaundice[7] is the first symptom. As a rule, the yellowish tinge gradually changes to a deep olive-green color, and with it the changes in the urine take place; gastro-intestinal dyspepsia is developed, and finally a veritable catarrh supervenes, with its full train of symptoms. Early in the disease weight and tension in the epigastrium and hypochondriac region are complained of, and enlargement of the liver and gall bladder is observed. After a time pruritus comes on, and in from two to four months hemorrhages ensue. Loss of flesh and strength rapidly takes place. Soon, if death has not in the mean time resulted from the original cause or from some intercurrent disease, the symptoms of cholæmic intoxication are likely to arise, and death results from this condition.

One cannot, within the limits of this article, discuss in detail all the forms of biliary stenosis and occlusion, and their differential diagnosis; persistent jaundice, the absence of bile in the stools and its presence in the urine, clearly indicate obstructive jaundice. There are some organic diseases of the liver, however, which give rise to jaundice in some other way than by means of occlusion. They should be distinguished from other forms of obstructive jaundice, on account of the opposite methods adopted for their treatment. Reference is made to atrophic and hypertrophic cirrhosis, to carcinoma, to simple and multiple abscesses, to simple and multiform hydatid disease, and to amyloid disease. The recognition of any of these is not difficult. The atrophic variety of cirrhosis is easily recognized by its well-known symptoms, but not so the so-called hypertrophic cirrhosis. The jaundice is intense, the liver enlarged and smooth, ascites is absent, paroxysmal pains occur, and irregular fever is present.[8] In other forms of obstruction the liver is not so large, the gall bladder is enlarged, while a distinct cause for the jaundice—as, for example, a tumor—may be discovered.

Having discussed the question of occlusion due to any one of the etiological factors previously noted, we may now be permitted to refer briefly, for diagnostic purposes, to these causal conditions.

1. FOREIGN BODIES.—If the obstruction be due to *worms*, the latter may be recognized by the age of the patient, and by the presence of the parasite in the ejecta. Their presence is further indicated by an attack of hepatic colic, but an absolute diagnosis cannot, and practically need not, be made. This, however, is not so in the case of hydatid cysts, which burst into the bile ducts, with symptoms of hepatic colic. The diagnosis, under these circumstances, can be more readily made: first, by the previous history and physical signs of an hydatid tumor; second, by the disappearance of the tumor after the colic; third, by the subsequent occurrence of fever and local inflammation; and lastly, by the appearance of sacs or hooklets in the vomited or aspirated matter.

Gall Stones.—It is of the utmost importance to determine the presence of biliary calculi. To accomplish this, is sometimes a very difficult matter; in fact, it is often a task impossible of accomplishment. The varying symptoms of cholelithiasis are so many that it is not possible to name one of them, or to present a group of them, for the purpose of making a diagnosis, without being able to give an exception to each and every one. The only absolutely definite sign is to see or feel the calculus. If one has been passed by the rectum, it probably was the cause of the obstruction; if it have facets, a fellow-calculus may be the cause.[9] If it is not detected in the stools, exploration of the gall bladder and bile ducts may be resorted to by opening the abdominal cavity. Martin-Solon (*Jour. des Conn. Méd.-Chir.*, Paris, 1849, xxxiii.) reports a case in which the stones could be detected on palpation if the patient took a forcible inspiration, the hand being on the gall bladder. He considered it a new mode of diagnosis.

Aside from these positive methods, a correct conclusion cannot be arrived at without a study of the case in its entirety; the age and sex of the patient, the habits, the family history, the temperament, all are important elements to be considered. If these circumstances are favorable, and if, in addition, the patient has had previous attacks of hepatic colic, *followed* by jaundice and the symptoms of duodenal catarrh; if constipation and putty-colored stools accompany the jaundice, the diagnosis is very probable. Then if, after impaction has taken place, the nutrition of the patient remains good for a long time, and the liver enlarges only slightly, while the gall bladder increases appreciably in size, it is scarcely possible to name any other affection as the probable cause of the symptoms.

Campbell (*Brooklyn Annals*) suggests that if, after aspiration of the gall bladder, bilious stools are present, calculi may be assumed to be the cause of the obstruction. The relief of the tension allows the stone to recede and the bile to escape.

2. DISEASES OF THE DUCTS.—*a.* Congenital closure. In an infant, a jaundice that continues for over four weeks, with supervening cholæmia, is due most frequently to this condition. *b.* Closure of the ducts by chronic catarrh of the duodenum, by adhesive inflammation of the ducts, by the cicatrization of an ulcer in the duct or at the duodenal orifice, and by fibrous bands. The first may be recognized partly by the history of the case and partly by the exclusion of attacks of catarrhal jaundice. Adhesive inflammation of the ducts is due either to the passage of biliary calculi or to a previous catarrh. The respective symptoms of the two must be considered in each case.

Ulcers in the bile ducts are due to gall stones, or are secondary to cancer or an infectious fever, as typhoid or cholera. In the former case, in addition to the symptoms of gall stones, we have, accompanying the ulceration, irregular chills and fever and extreme exhaustion, conditions not likely to be present in the early stages, at least, of simple impaction. If the symptoms of occlusion become developed after such phenomena or after an infectious fever, the exciting cause is probably the cicatrization of an ulcer in the duct. The well-known symptoms of duodenal ulceration precede for a long time the symptoms of obstruction of the biliary passages from this cause, and while it may be said that the gall bladder is enlarged under such circumstances, it is not necessarily so when the seat of ulceration is in the duct. Closure of the ducts by fibrous bands may be inferred, if the cause (as syphilis) and the symptoms indicate a perihepatitis, and if other evidence of previous inflammatory trouble be present, as atrophy of the liver, or ascites, etc., due to pressure on the portal veins.

3. DISEASES EXTERNAL TO THE DUCTS.—*a.* Carcinoma and other neoplasms of the liver and surrounding organs. A recognition of these affections can be obtained by the exclusion of other causes of obstruction, by the presence of tumors or nodules, and by the physical signs discoverable on palpation, etc.; also, when these are present, by the alterations of the functions of adjacent organs, and by the presence of the symptoms of malignant disease of these organs; and finally by the duration of the disease, the stenosis from carcinomata being of shorter course than that due to other causes. *b.* Enlarged lymphatic glands. Obstruction from this cause is probable, if there be elsewhere present any of the well-known causes of hypertrophy of these glands, as carcinoma, tuberculosis, amyloid disease, etc. Amyloid disease but rarely causes jaundice, except in this way; its symptoms are too well known to be detailed in this article. *c.* Aneurism. This rare form of occlusion may be recognized by the pressure symptoms of a tumor located in the region of the duodenum, and by the physical signs of aneurism.

The *course* of the disease, in occlusion of the biliary duct, is a chronic and most frequently a progressive one. It is a gradual march to death, except in cases in which foreign bodies cause the occlusion. Under these circumstances their removal by ulceration or the escape of bile around them may be followed by recovery. Death is the result of the original cause of the disease in many cases. Exhaustion or cholæmia often brings about a fatal termination. The duration varies with the cause, and is modified by the onset of accidental complications. Complete occlusion may terminate in recovery even after a lapse of six years. The prognosis is unfavorable, depending on the nature of the causal lesion. Hemorrhages render the prognosis very grave. The supervention of symptoms of cholesteræmia is serious. The return of color to the stools is of more favorable import than is a change in the skin discoloration.

The treatment is mainly directed to the relief of symptoms. Medicinal remedies are of but little avail, and resort must be had to surgical measures. The regulation of the diet is of the utmost importance to the conservation of life (see section on *Catarrhal Inflammation*, etc.). Means must be taken to overcome the gastro-intestinal symptoms that result from the absence of bile in the intestines. The bowels must be regulated, the secretion of the kidneys kept active, and the activity of the cutaneous glands promoted. Cholecystotomy, with the establishment of a permanent fistula, may be resorted to, and it may, by relieving pressure in some cases of gall stone or parasitic obstruction, promote a cure. Cholecystduodenostomy has resulted in success in some instances and the advisability of resorting to it should be considered in a case of complete occlusion.

IV. ENLARGEMENT OF THE GALL BLADDER.—Under this caption all forms of enlargement of the gall bladder will be described, as it is by the clinical study of this manifestation of the disease that we, to a large extent, determine the nature of the ailment and the indications for treatment.

The gall bladder is enlarged from the accumulation within it of bile, of pus, of mucus, and of gall stones, and from disease of its walls—carcinoma. Increase in size from bile, pus, or serum is usually styled simple dilatation. Carcinoma of the biliary passages will be treated of in a separate section. Accumulation of the fluids just indicated is due either to obstruction of the duct, or, in rare cases, to a paralysis of the muscular coat of the gall bladder from overdistention. The dilatation from bile or pus may be temporary, and in such a case is caused by an obstruction catarrhal in nature, or by the presence of a gall stone, which acts as a ball-valve in the lumen of the ducts. Enlargement from accumulation of bile is not common, but may occur with a concretion in the common duct. It is usually of short duration, the bile being absorbed and replaced by mucus.

The walls of the gall bladder are uniformly distended and thinner than normal, the mucous membrane is smooth, and there are no adhesions to the surrounding parts. Sometimes the dilatation is extreme. From a patient of Babington's, three wash-basinfuls of fluid were withdrawn, and in another case the gall bladder was so distended as to give the patient the appearance of having an ascites (Coupland). Lawson Tait and Kocher report cases in which distended gall bladders were mistaken for ovarian cysts. Waring mentions a specimen in which the lower end of a distended gall bladder formed the contents of a sac of a femoral hernia. The contents may consist at first of bile, but as the obstruction continues, this becomes more and more intermingled with mucus.

If serum accumulates, causing enlargement (hydrops cystidis felleæ), the obstruction is usually one that has existed for a long time. The inner surface of the mucous membrane is like a serous membrane in appearance, and the accumulated fluid is the result of secretion from this membrane. Adhesions are also absent in dropsy of the gall bladder, and the walls of this organ are much attenuated. It is usually found that in cases of obstruction by gall stone in the common duct the gall bladder is small and contracted, due probably to repeated irritations from stones, the subsequent fibroid changes successfully resisting distention. Distention of the gall bladder with marked jaundice is more frequently met with in new growths of the bile ducts or of the head of the pancreas. The chemical character of the fluid has already been described in section III.

Empyema or abscess of the gall bladder results from an infection by micro-organisms, either following upon some obstruction or irritation, or developing spontaneously. The condition is most frequently associated with gall stone, but tumors of the bile duct, typhoid and other fevers may be predisposing factors. Robson considers that "infection by pyogenic organisms is probably in every case the true exciting cause." The same anatomical changes are presented as have been described in the section on Purulent, Ulcerative, and Croupous Inflammation of the Gall Bladder, etc. The walls of the organ are friable and easily ruptured. Adhesions to the surrounding parts are usually formed, and a fistula is established. Pus, or pus and bile, and almost always gall stones, make up the contents. The accumulation of gall stones in the gall bladder, causing enlargement, is not uncommon.

Symptoms.—The presence of a tumor in the region of the gall bladder is common to all forms of enlargement. The nature of a tumor observed in this region is determined by its position, size, and shape, by the characters revealed by palpation, and by the nature of its contents. The gall bladder may be known to be enlarged when it is situated under the free border of the ribs, at a point where it is crossed by a line drawn from the tip of the right shoulder to the symphysis pubis (Janeway). As enlargement progresses, the direction which it takes is usually toward the umbilicus, or into the iliac fossa. An area of resonance intervenes between the tumor and the liver, and the intestines are never in front of the organ. The tumor may be pyriform, oval, semiglobular, reniform, or heart-shaped. The size of the tumor varies from that of a walnut to that of a child's head; it may even distend the ribs on both sides (Coupland). On palpation, the tumor may be found to be fixed or movable, tender on pressure, firm, elastic, and fluctuating. If enlarged by gall stones, a grating sensation may be experienced on palpation, and the mass will be hard and firm.

The general condition of the patient and the symptoms presented depend on the cause of the obstruction (see the section on Purulent Inflammation, etc.).

Diagnosis.—A differential diagnosis must be made between enlargement of the gall bladder and many forms of abdominal tumors—hepatic, gastric, duodenal, pancreatic, and lymphatic tumors (see section on Occlusion, etc.). Abscess of the liver and hydatid disease must be excluded. In the former, the cause, the general and local symptoms, the absence of jaundice, the induration, and then the softening and fluctuation of the swelling, should be noted. The painless, slow course of hydatid disease, the broad base of the cyst, the fremitus, and the result of tapping will serve, if taken with the negative symptoms of enlargement of the gall bladder, to render the recognition of this disease possible. In multilocular hydatid disease the tumor resembles an enlarged gall bladder containing calculi; like the latter, it is nodulated, hard, and tender, but it is associated with early jaundice, ascites, an enlarged spleen, œdema of the lower eyelids, great emaciation and prostration, with rapid decline of the patient's general health—conditions which, excepting jaundice, are not likely to be present in gall stones. Floating kidney and renal and ovarian tumors have been mistaken for enlargement of the gall bladder. Such an error will not often be made if it be remembered that the enlarged gall bladder is more movable at the lower than at the upper portion; that one end is larger and more rounded than the other; that fluctuation may be present, and that biliary symptoms generally exist; while the absolute sign of floating kidney, an abnormal area of resonance in the renal region, is absent. Tapping would also be invaluable as an aid. In sarcoma of the kidney, in hydronephrosis, and in pyonephrosis, there are changes in the urine to call attention to them. Those renal tumors at first always have the intestines in front of them; they are not influenced by respiratory movement, nor is their area of dulness on percussion continuous with that of the liver; in hydronephrosis a previous renal colic and possibly frequent discharges of urine followed by diminution in size of the tumor occur. These questions of diagnosis arose in the study of the case of Kocher. He relied much on the results of exploratory puncture, as previously discussed. A connection between the tumor and the uterine appendages and the seat of origin and direction of development of the growth are the points in favor of ovarian tumor; in addition to which, if the fluid be characteristic, the diagnosis of such a tumor would be doubtless correct. A recognition of the various forms of enlargement of the gall bladder can be made by attention to the results of palpation and exploratory puncture and by a consideration of the history of the case. A cancerous tumor of the gall-bladder is fixed, painful, not very large, and is attended by gastric symptoms and cachexia.

Course, Duration, Prognosis.—These all depend upon the cause. Abscess of the gall bladder is manifested by active symptoms and runs a rapid course. It may terminate favorably by communicating with the exterior, or the stomach, or the intestines, although long-continued discharge from the fistula might be serious. The prognosis of this condition depends on the direction in which the pus may burrow. Accumulations of bile are serious, on account of the cause of the collection, and the course and prognosis depend upon the concomitant pathological phenomena. Dropsy of the gall bladder is latent and chronic; the prognosis is not unfavorable.

Treatment.—Tapping of the gall-bladder is indicated in cases of accumulation of bile or serum, although to-day a surgeon will prefer to open directly into the gall-bladder; purulent collections are practically always to be treated in this manner. At the same time a supporting and stimulating line of treatment must be carried out. The same indications are to be met in accumulations of bile in the gall bladder as in occlusion of the biliary passages.

V. MORBID GROWTHS OF THE GALL BLADDER AND GALL DUCT.—Here and there may be found an isolated report of a case of polypus, fibroma (submucous), myxoma, or tuberculosis of the biliary channels, but they are uncommon. Rolleston reports an instance in which a papilloma of the bile duct in intimate association with a stone was removed; some months later the patient returned with a growth in the same region, probably malignant. Bishop (*Lancet*, July 18th, 1901) described a large, non-malignant, cystic growth of the gall bladder and cystic duct. The epithelial lining of the cavities was regularly formed and no sign of cancerous formation could be detected. Kelynack (*Med. Chron.*, November, 1897) has collected instances of fibroma, myxoma, adenoma, and papilloma, though he considers most of the latter to have been epitheliomata. Primary cancer is more frequent than is generally supposed, the secondary form is very common. One of the writers (Musser) has tabulated seventy-eight cases of primary cancer of the gall bladder, and ten cases of cancer of the bile ducts. Kelynack amongst 4,278 cases of cancer finds 8 instances of the former and 2 of the latter. Fütterer (1897) and Rolleston (*Clin. Journ.*, 1897) have reviewed this question.

Primary Cancer of the Gall Bladder. (Musser: "Cancer of Gall Bladder and Bile Ducts.")—*Etiology.*—The *age* was not recorded in 8 cases. Two cases occurred under thirty; 13 between forty and fifty; 19 between fifty and sixty; 14 between sixty and seventy; 13 between seventy and eighty, and 1 in a patient over eighty years of age. The variety of carcinoma was not recorded in 28 instances. In the remainder, at no period of life was there any remarkable tendency to one variety rather than to another. The extreme age at which the growths were found is noteworthy. The *sex* was recorded in 75 cases, of which 61 were in females and 14 in males. The varieties were equally distributed among the men. Among the women, 18 had encephaloid, 8 scirrhus, 6 epithelioma, 5 colloid, and 2 villous carcinomata; 2 others had sarcomata. Occupation, heredity, and habits played no part in the etiology. Nor did previous health, mental states, or accidents in any way predispose to the disease. Four cases were recorded with antecedent history of gall stones. In the reports of the autopsies, however, it is noted that in 52 of the 78 cases gall stones were found. Kelynack's article (*Med. Chron.*, November, 1897) includes the most valuable collections of cases up to this time; very complete statistical reports are given.

Symptoms. (Musser: "Cancer of Gall Bladder and Bile Ducts.")—Jaundice was present in 51 cases. It developed rapidly in 1, was slight in 6, recurring in 1, and continued for periods varying from one week to three months. The cancerous cachexia was observed in 12 cases. Pain was present in 39 instances. It was seated in the right hypochondrium in 22 cases. Nine suffered from epigastric pain. It was described as colicky (8 cases), as lancinating, as paroxysmal, as wandering, as constant, and as severe. Tenderness on pressure was elicited in a few instances. Fever was present in a large number, viz., in 13 cases. It was intermittent in 2, continued in the others.

The gastro-intestinal symptoms were marked. Nausea was noted in 5 cases, and vomiting in 30. The appetite was lost in 14; constipation was present in 19 cases, diarrhœa in 11. Ascites developed in 16 cases; œdema, appearing late in the disease, in 9. Exhaustion ensued in 15; emaciation continued and became excessive in 36 instances. Hemorrhages occurred, late in the disease, in 5 cases, and grave cerebral symptoms in 7. Physical signs: A tumor was observed in 34 instances; hard and firm, 19 times; irregular and nodular, 8[10]; round, oval, pyriform, cylindrical, and smooth, were the terms used to describe it. In 8 it was movable, in 6 fixed. It disappeared on pressure in 1 instance. It varied in size from a hazelnut to a child's head. Ten times a record of pain in the tumor was made; 4 times the tenderness was marked. The tumor was said to be situated in the region of the gall bladder (10), in the umbilical region (7), in the right hypochondrium (10), or in close proximity to these situations. The liver was enlarged (21), atrophied (1), hard (2), irregular (2), nodular (3), or tender (2). The veins over the surface were enlarged in 2 instances.

In fine, emaciation, jaundice, cachexia, pain in the region of the gall bladder, with fever, nausea, vomiting, and loss of appetite, with or without diarrhœa, are the prominent symptoms of cancer of the gall bladder. To corroborate the surmise of its presence, a tumor in the right hypochondrium, tender on pressure, and the seat of pain, and nodular in character, would usually be found.

Morbid Anatomy.—The encephaloid variety is found most frequently, the scirrhous next, and then the epitheliomatous, colloid, and villous. Kelynack gives epitheliomatous growths the first place in order of frequency, with scirrhous next. The growth begins at the junction of the cystic duct with the bladder and involves the entire organ, leaving scarcely a trace of it, or infiltrates the coats and encroaches on the cavity. Again, a few nodules are seen underneath the mucous membrane, or a dense thickening of the walls, caused by new formations, takes place, especially at the cystic duct, or finally the gall bladder is represented by a nodular mass. The mucous membrane is destroyed entirely or ulcerated at various points over the cancer, or is the seat of intense inflammation. Fungoid cauliflower or villous excrescences grow into the cavity of the bladder, or the surface of the mass may be covered with papillæ with bulbous extremities. The tumor may be dense, firm, without juice, or a soft, pulpy mass. In some instances the gall bladder is reduced in size, very often it is enlarged, even enormously distended. The peritoneal investment is intimately adherent and thickened; subperitoneal nodules are seen, or the external surface in the colloid variety partakes of its peculiar characters. Adhesions are formed between the diseased gall bladder and the adjacent organs; degeneration of the walls, and at times rupture, take place. Ulceration and perforation are very common. Fistulous communication is thus established between the gall bladder and the duodenum, the colon, or the stomach. In the course of the disease gall stones are often discharged in this way. The centre of the carcinomatous mass is made up of soft, pulpy detritus, or of a thick, creamy matter. In it gall stones are also found, sometimes firmly encapsulated by the growth; or, if the cavity of the gall bladder remains, it is filled with calculi, with pus, bile, blood, or mucus, singly or combined. In 52 instances out of 78, gall-stones were present. The new formation spreads to contiguous structures;—thus the liver, colon, stomach, etc., may be involved. Changes are found in the liver and in the ducts, due to obstruction of the large bile ducts. (See Sections II. and III., for description.) Peritonitis (local) is usually present; an acute inflammation is set up by rupture. Secondary deposits may also be found in the abdominal lymphatic glands, the omentum, the suprarenal bodies, and the pleura.

Diagnosis.—The marked symptoms detailed in the clinical history are to be borne in mind. The character of the tumor, its seat, its mode of growth, its immobility, pain, and tenderness, are important. The occurrence of jaundice and vomiting, the passage of calculi (by a fistula leading to the colon) per rectum, without relief to obstruction, and the occurrence of emaciation, make a diagnosis almost positive. The age and the sex are important factors, and a history of the jaundice is of aid in the diagnosis.

Relation of Gall Stones to Carcinoma.—This is believed to be causal. The frequent occurrence of this disease in the same sex in which biliary calculi are most common, is strong evidence. But a case of Quetsch's (*Berl. klin. Wochenschrift*, 1885, No. 42, p. 672) confirms this opinion more decidedly than does any previous clinical evidence. The patient, a female, was subject to biliary calculi, and a biliary cutaneous fistula had been formed. Subsequently, a carcinoma of the gall bladder developed in the presence of the calculi which did not pass, and, no doubt, were the cause of the local irritation. Zenker found gall stones in 85 per cent. of cases of cancer of the gall bladder. Similarly high percentages were found by Courvoisier, Brodowski, Gayle, Bertrand, and others; Siegert, in 95 per cent. of primary carcinomas of the gall bladder, found stones associated, but in only 15 to 16 per cent. of secondary carcinomas was this the case. In 4 cases of primary carcinoma of the liver, reported by Beadles, stones were also present, while none were seen in 36 secondary hepatic carcinomatous growths. Others believe that the calculi develop secondarily from stagnation of the bile and precipitation of its constituents.

Duration.—This has been placed at several years by Villard; in other cases death occurred within three months after the first symptoms developed.

The *prophylactic treatment* consists in the removal or prevention of formation of the calculi, and the *treatment* of the disease, after it is once manifested, is purely symptomatic. Robson, however, has removed the gall bladder and part of the liver in five cases, with more or less encouraging results in four of them. As one of the cases was shown at operation to be a chronic inflammatory condition of ducts, gall bladder, and adjoining viscera instead of carcinoma, the value of an exploratory operation is certainly suggested.

VI. PRIMARY CANCER OF THE GALL DUCTS.—It may develop within the liver or in the larger ducts. The most common point of origin is at the mouth of the common duct or at the junction of the cystic and hepatic ducts. A firm mass of newly formed tissue surrounds the duct or invades its walls. The lumen is almost or completely obliterated; its inner surface is the seat of ulceration, at certain points, or of papillary growths. A fungous growth projected from the mouth of the common duct in a case reported by Stokes. The anatomical changes of occlusion and stenosis are seen in the liver and ducts. Secondary deposits are found generally in the liver only, along the ducts. Kelynack[11] discusses primary cancer of the ducts and has collected 26 cases. A diffuse growth was most frequently met with post mortem. Edes[12] and Rolleston[13] are more recent contributors to the subject, dealing particularly with cancer of the extreme end of the common bile duct. Halsted[14] has removed a columnar-celled carcinoma from the ampulla of Vater.

The symptoms common to carcinoma and to biliary obstruction are present. Rarely is the growth large enough to be recognized by palpation. Death is rapid and due to occlusion of the ducts, leading to bile intoxication or purulent inflammation.

VII. Congenital Defects of the Gall Bladder and Gall Ducts.—The gall bladder may be absent entirely, without serious inconvenience; a shrivelled pouch or a contracted tube takes its place. In atresia of the ducts, jaundice, umbilical hemorrhage, and marasmus are present during life. The jaundice is present at birth, or makes its appearance a few days afterward, persists, and deepens. The stools show an absence of bile; the urine is bile-tinged. There is from the first a tendency to hemorrhages, and this increases ecchymosis under the skin; bleedings from the mouth, nose, or bowels take place.

Umbilical hemorrhage, occurring after the separation of the cord, is especially marked. As the child grows older it loses in flesh, becomes extremely weakened, and dies of cholæmia or exhaustion, in spite of an ability to take much nourishment. At first the liver is normal, but if the child lives it becomes very large, and the spleen is likewise increased in size. Ascites may develop. If hemorrhages do not occur, the child lives many months. In a case reported by Lotze, the child lived seven months.

R. Lomer [15] reports a curious case. It was one of congenital obliteration of the right hepatic and the cystic ducts. The whole right lobe had undergone cystic degeneration and was shrunken, the gall bladder was obliterated, but the left lobe remained normal. He analyzes a series of cases, and, from the fact that usually the parents are syphilitic and several of their children are similarly diseased, he holds that an intra-uterine hepatitis of syphilitic origin is the cause of the disease. This is the usually accepted explanation of the pathology of congenital disease of the ducts. The obstruction, which is fibrous, may be in a main duct or in one of its branches. The gall bladder may be normal, but contains a serous fluid. It may be obliterated or remain as a fibrous cord. The ducts in the liver may be dilated, or some may appear like fibrous cords. Sometimes the portal fissure is the seat of local perihepatitis, and usually the surface of the liver is involved. The liver is icteric, the seat of connective-tissue overgrowth, or atrophied. Some parts become cystic. Rolleston and Hayne [16] describe a congenital obliteration of the bile ducts giving rise to an advanced hepatic cirrhosis; Thompson (Allbutt's "System of Medicine" and Thesis, Edinburgh, "Congenital Obliteration of Bile Ducts") has collected fifty such cases. Ford [17] gives cases of congenital obstruction producing the so called biliary cirrhosis.

The jaundice due to congenital defects of the ducts is to be distinguished from that jaundice-like discoloration of the integuments, conjunctiva, etc., that is physiological. In this condition, which is common in new-born infants, bile is present in the stools. Jaundice of the simple catarrhal variety also occurs in infants. It usually responds promptly to treatment, and has not the malignant aspect of disease dependent upon deficiency of the ducts. Then, again, a pylephlebitis occurs sometimes in infants. In this case fever and the usual evidences of pyæmia are present.

VIII. Parasites.—They may develop within the biliary passages (distoma), they may emigrate from the intestines (round worm), or they may find their way into the ducts by ulcerative action (echinococcus). Rarely, the latter develop within the ducts.

1. *Distoma hepaticum* (*large liver fluke*) *and Distoma lanceolatum* (*small liver fluke*).—Common in sheep and cows, rare in man. The large fluke is found in the gall bladder or large bile ducts; the small one generally in the finer ducts. Both species may occur in the same subject. The latter variety produces the most notable changes in the liver.

The presence of these parasites sets up a chronic catarrhal and suppurative inflammation of the ducts. Enlargement of the gall bladder and ducts occurs secondarily. A fibrous inflammation of the walls takes place, with secondary calcareous degeneration of the products of inflammation; the ducts become much enlarged and thickened, and the lumen is dilated. Occlusion of the ducts results on account of the inflammatory disease and the presence of the parasites in the canal. By necessity, therefore, we have the symptoms, previously noted in this section, of the above anatomical changes, and of obstructive jaundice. In addition, nervous symptoms of a reflex nature—as syncope, convulsions, or aphonia—may be present. A positive diagnosis can be made only by finding the parasites in the vomited matter, or in the fæces. Death occurs sometimes on account of the inflammatory complications, or from exhaustion.

2. *Round Worms* (*Ascaris lumbricoides*).—They usually wander from the intestines, and are found with their head toward the liver. Rarely, after adhesive inflammation and fistulous communication between the gall bladder or ducts and the intestine, worms are found in the biliary passages. The number of them varies—from one to three or four, usually. They are often found alive on making an autopsy, or have died before the death of the patient, and are soft and macerated. Their presence excites catarrhal inflammation, causes occlusion and, secondarily, a purulent cholangitis, a dilatation of the ducts, and subsequent atrophy of the liver, or the formation of multiple abscesses. When limited to the gall bladder, they cause enlargement and inflammation of that organ. The dilatation of the ducts is usually general; sometimes local sacculated dilatations are observed, in which worms lie rolled up.

The symptoms—if the worm has recently migrated into a duct—are like those of hepatic colic. Later, the symptoms and signs of obstructive jaundice occur, and then those of purulent cholangitis. A history of an attack of worms, the presence of the parasite in the ejecta, and the age of the patient furnish valuable corroborative evidence. Further, intestinal and nervous symptoms due to worms are said to be present.

3. *Echinococcus* (*Hydatid Disease of the Bile Ducts*).—Either an hydatid cyst may press upon one or more of the ducts, causing occlusion of them, or complete obliteration of their lumen, or entire destruction of them (Leroux); or the sac may ulcerate into the ducts or bladder, and the vesicles pass by this route into the intestines, with symptoms of hepatic colic; or, finally, it may cause occlusion, dilatation, and inflammation of the biliary passages. This process may terminate in suppuration and gangrene of the cyst, and is usually fatal. The symptoms of obstructive jaundice of a high degree, and of the local inflammatory changes, indicate this pathological condition. The presence of hydatid hooklets in the ejecta from the stomach or bowels, a previous history of a painless enlargement of the liver, and the results of tapping or exploratory puncture, would confirm one's opinion of the presence of hydatid disease. Finally, the gall ducts are seriously invaded in that rare manifestation of hydatid disease known as multilocular echinococcus. In this instance the walls of the ducts are thickened, hard, and rigid, and the lumen is effaced, by the presence of the vesicles in the tissues. Secondary inflammation, suppuration, and dilatation, etc., may arise in these cases. The symptoms of this manifestation have been considered in the section on Occlusion of the Ducts.

It is interesting to note that the bile, some authorities believe, is capable of killing these parasites.

John H. Musser.
Norman B. Gwyn.

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[3] See Trans. Path. Soc., vol. viii., and Am. Jour. of the Med. Sciences, July and October, 1884, for cases of chronic catarrhal jaundice by the writer.

[4] Deutsch. med. Wochen., 1895, No. 15.

[5] Amer. Journ. of the Med. Sciences, November, 1901.

[6] Bulletin of University of Pennsylvania, September, 1901.

[7] Jaundice is used in a general sense. For a further discussion of symptoms and effects, see *Icterus*.

[8] See Pathological Society's Transactions, Philadelphia, 1877–78, Am. Jour. of the Med. Sciences, July, 1884.

[9] In cases of cancer of the gall bladder and ducts, calculi are often passed.

[10] Numbers record frequency of the presence of a stated fact in the seventy-eight cases.

[11] *Loc. cit.*

[12] Boston Med. and Surg. Journ., March 7th, 1901.

[13] Lancet, February 16th, 1901; Med. Chron., 1896.

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[15] Lomer: Ueber einen Fall von congenitaler partiellen Obliteration der Gallengänge. Virchow's Arch., Band 99, p. 130.

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GALLIC ACID.—By exposure, to the atmosphere, of galls in the presence of water, chemical conversion of the tannic acid of the galls takes place, resulting in the formation of gallic acid, $HC_7H_5O_5,H_2O$. This body is official in the United States Pharmacopœia under the title *Acidum Gallicum,* Gallic Acid, and presents itself as "white, or pale fawn-colored, silky, interlaced needles, or triclinic prisms; odorless; having an astringent or slightly acidulous taste; permanent in the air. Soluble at 15° C. (59° F.), in 100 parts of water, and in 5 parts of alcohol; in 3 parts of boiling water, and in 1 part of boiling alcohol. Also soluble in 40 parts of ether, and in 12 parts of glycerin. Very slightly soluble in chloroform, benzol, or benzin" (U. S. P.). On heating, the acid first loses its water of crystallization, then melts, and finally is decomposed, and consumed without residue.

Gallic acid is purely but feebly astringent, and seems practically devoid of any other physiological property. Taken internally, it does not poison, nor constipate, nor even disorder the stomach unless in excessive dosage. It does not coagulate albumin, and so, when swallowed, is readily absorbed. After absorption it appears speedily in the urine, as is demonstrable by chemical tests. *Therapeutically,* the only reputation of gallic acid is for internal giving for the control of hemorrhages from inaccessible parts—for which purpose the efficacy of the medicine is esteemed very differently by different practitioners. Since, in the application in question, the acid must act by local contact as presented to the bleeding vessel in solution in the blood, it is evidently necessary for success that the charge of acid to blood shall be as great as possible. Full and frequent doses, therefore, are required by the indication. Gallic acid has been given without untoward effect in dosage of 0.65 gm. (gr. x.) every three hours, unremittingly, for three weeks. It may be prescribed in pill, powder, or mixture. *Edward Curtis.*

GALLICIN $[C_6H_2COOCH_3(OH)_3]$ is prepared by heating a methyl alcohol solution of gallic or tannic acid with strong sulphuric acid, or by passing dry hydrochloric acid gas through the solution. It crystallizes in rhombic prisms or fine needles, which are freely soluble in water and alcohol. It is used as an antiseptic, non-toxic dusting powder, and, in solution, in conjunctivitis.

W. A. Bastedo.

GALLOBROMOL—dibromogallic acid $[C_6Br_2(OH)_3COOH]$—is a colorless or slightly grayish-red powder, composed of fine acicular crystals, and obtained by the action of bromine on gallic acid. It is slowly soluble up to ten per cent. in cold water (Merck), and dissolves readily in boiling water, alcohol, or ether. It has been used as a bromide in neurotic conditions and epilepsy, but has been found by Lépine to cause in a dog slowing of the heart, depression of respiration, fever, hæmoglobinuria, convulsions, and death. It is of more use locally, as an antiseptic and astringent, as in eczema, or in gonorrhœa, cystitis, or epididymitis. For cystitis it is used as an irrigation in two to four per cent. solution; for urethritis as an injection; and for eczema as a lotion, ointment, or dusting powder of one to two per cent. strength.

W. A. Bastedo.

GALLOFORMIN $[C_6H_2(OH)_3COOH(CH_2)_6N_4]$ is a condensation product of gallic acid and hexamethylene tetramine. It forms very hard, refractive, acicular crystals, soluble with difficulty in water, alcohol, ether, and glycerin, and insoluble in benzol and fixed oils. It is very unstable, readily yielding formaldehyde gas, so is used as an antiseptic both internally and externally. It is decomposed by heat, acids, or alkalies.

W. A. Bastedo.

GALL, OX.—Fel Bovis.—"The fresh bile of *Bos Taurus* L. (class *Mammalia;* order *Ruminantia*)," (U. S. P.)

A brownish-green or dark green, somewhat viscid liquid, having a peculiar, unpleasant odor, and a disagreeable, bitter taste.

Specific gravity: 1.018 to 1.028 at 15° C. (59° F.).

It is neutral, or has a faintly alkaline reaction on litmus paper.

A mixture of 2 drops of ox gall and 10 c.c. of water, when treated, first, with a drop of a freshly prepared solution of 1 part of sugar in 4 parts of water, and afterward with sulphuric acid, cautiously added, until the precipitate first formed is redissolved, gradually acquires a brownish-red color, changing, successively, to carmine, purple, and violet.

Purified Ox Gall, Fel Bovis Purificatum (U. S. P.).

Fresh ox gall, *three hundred cubic centimetres*....	300 c.c.
Alcohol, *one hundred cubic centimetres*..........	100 c.c.

Evaporate the ox gall, in a tared porcelain capsule, on a water bath, to about *one hundred* (100) *grams,* then add to it the alcohol, mix the whole thoroughly, and set it aside, well covered, for three or four days. Then decant the clear solution, filter the remainder, and, having mixed the liquids and distilled off the alcohol, evaporate the remainder to a pilular consistence.

A yellowish-green, soft solid, having a peculiar odor, and a partly sweet and partly bitter taste.

Very soluble in water and in alcohol.

A solution of 1 part of purified ox gall in about 100 parts of water behaves toward sugar and sulphuric acid in the same manner as the solution mentioned above.

An aqueous solution of purified ox gall should be clear, and should remain transparent upon the addition of an equal volume of alcohol (evidence of proper purification).

This complex substance in its crude condition consists of about ten per cent. of solids and ninety of water.

The most important solid constituents are the *sodium salts* of *taurocholic* and *glycocholic acids,* and several not very well distinguished coloring matters (*bilirubin, biliverdin,* etc.). Besides these it also contains a number of decomposition products, *cholesterin, urea,* etc., and some *fats* and *mucus.*

Further than to show its practical identity with that of the human subject, the study of the specific composition of ox gall is unimportant.

For the same reason the study of its action pertains wholly to physiology. We know that bile has no business in the stomach, although it appears that its entrance there, in certain morbid conditions, may exert a stomachic effect, without seriously inhibiting digestion, and its therapeutic use may be serviceable in this way. It must, however, be remembered that the properties of the bile itself are subject to change in the stomach, so that suitable measures must be taken in its administration (see below), when the intestinal action is desired.

It is equally well established that bile in the circulation acts as a poison, although there are some facts to suggest that its antitoxic action there may at times more than counterbalance such objection.

It is then in the intestine and in the liver that we must look for the beneficial effects of the administration of bile. In the former it is a valuable antiseptic, peristaltic stimulant, chemical synergist of certain purgatives, and promoter of the absorption of fat. None of these processes requires discussion. All can be effected by ox gall, properly administered, as by the natural secretion. Upon the liver, the drug has the effect of a direct cholagogue, that is, an agent increasing the actual secretion of bile, and about the only one known. Since the constituents of the bile decomposed in the intestine are returned to the liver to be again recombined, we should naturally expect this increase to be produced. It appears, however, that the increase is greater than the ratio thus accounted for, and it is apparent that the bile salts exert a stimulating effect upon the secreting mechanism. The following concerning the use and administration of the drug may well be reprinted from the last edition of this work.

The action of ox gall in assisting the absorption of fats and oils, and its aid in maintaining intestinal antisepsis, has suggested its use as a proper means of treating typhoid fever. Dr. Adolph Zea reports the result of ten cases in his own ward, and forty-eight cases treated by medical friends, as very gratifying. His method of conducting the case is as follows: If the case is seen early, a dose of calomel is given to relieve the digestive tract of its contents; alcohol in the form of whiskey is given at first as a stimulant, and, if additional stimulation is required, strychnine, caffeine, ammonia, camphor, or small doses of quinine; dilute muriatic acid in large quantities of water as a beverage, and fel bovis purificatum siccum, in doses of two to four grains, three to six times a day in pill form or capsule. The diet consists of fluids—milk, gruel, beef-tea—in small quantities frequently given. The milk should always be boiled, but may be given hot or cold according to the wish of the patient. Preparations of beef extracts and juices may also be given.

The benefit of this treatment is shown in a reduction of the temperature after the drug has been given for a few days, and a freedom from all distressing abdominal symptoms and complications. Convalescence is also thought to be more rapid than under any other line of treatment.

It has been very properly pointed out that the enclosing of the dose in *keratin* tends to prevent changes in it by the acid gastric juice, in its passage through the stomach.

Its injection into the rectum, in twenty-grain doses well diluted, tends to clear that organ of fæces.

Henry H. Rusby.

GAMBOGE.—Cambogia.—"A gum resin obtained from *Garcinia Hanburii* Hook. f. (fam. *Guttiferæ*)" (U. S. P.). (The family is now called *Clusiaceæ.*) This genus comprises about forty species of Eastern tropical evergreen trees with yellow juice. Other species yield the Mangosteen fruit and bark, and the Kokum butter. The gamboge tree is a native of Cambogia, Siam, and Cochin China, whence the supply of the gum resin for European and American consumption is obtained; but there are besides several other species of *Garcinia* in India, China, and the Asiatic islands, which supply similar products, if not exactly the same. Gamboge is collected by cutting or wounding the twigs or trunks, when the bright yellow latex flows slowly out, and is collected in vessels, usually bamboo joints, fastened at the lowest part of the incisions. Here it slowly hardens, or is perhaps dried over a fire, until a solid mass results, of the shape, usually cylindrical, of the containing vessel. The bamboo is then split off, and the gamboge is packed in large boxes for transportation.

That thus collected in bamboo joints is known as "pipe-gamboge." Saigon, or "purse" gamboge, is collected in pockets of leaves or cloth, six or eight inches long by three or four broad. It is usually a little darker than the former. When run or massed into large blocks or tubs, it is called "cake gamboge," or "gamboge in sorts."

The pipe gamboge is preferred, not only because it represents the typical quality, but because it is almost invariably pure and clean. The large cakes are liable to extensive adulteration with stones and pieces of iron. Being often formed in tubs or boxes, the gamboge is very apt to come into contact with nails or other metal, which turns it dark for a considerable distance from the offending body.

Gamboge has been used in China and India as a pigment for many centuries, and appeared as a purgative in Europe early in the seventeenth century. Its use in medicine, however, has always been insignificant in comparison with its consumption as a yellow paint, for which use it is hardly excelled by any pigment.

The best of that which reaches us is in cylindrical pieces, usually hollow at the centre, 2 to 5 cm. (1 to 2 in.) thick, longitudinally striate on the surface; fracture flattish-conchoidal, smooth, of a waxy lustre, orange-red; inodorous; taste very acrid; powder bright yellow, sternutatory, free from starch.

Gamboge should yield not less than seventy per cent. of resin and not over three per cent. of ash.

It does not dissolve in water, but forms a very fine, smooth, yellow emulsion with it, and it is wholly soluble in potassa solution.

Gamboge contains about seventy-two (Christison) per cent. of yellow resin called *gambogic acid*, an orange-yellow, tasteless, and odorless mass, soluble in alcohol and ether, but not in water, having the purgative properties of gamboge, but less intensely than the crude gum resin itself. It also contains fifteen or more per cent. of *gum*, a little water, and some impurities. Its activity is proportional to the percentage of resin in it.

Action and Use.—This is one of the most violent of hydragogue cathartics, producing abundant watery stools and considerable griping, on which latter account it is not often now given alone, or for its full effect. It is, however, frequently added in small doses to the other cathartic combinations, and experience has proved its usefulness. It is especially valuable in such conditions as lead colic and seasickness, where the bowel requires powerful stimulation.

The full dose of gamboge is about 0.3 gm. (= gr. v.), but less is advisable in compositions; the maximum daily quantity is stated by the German Pharmacopœia to be 1 gm. It is an ingredient in the compound cathartic pills (*Pilulæ Catharticæ Compositæ*, U. S. P.), each of which contains about a quarter of a grain.

W. P. Bolles.

GANGLION. See *Bursæ.* (*Surgical.*)

GANGRENE. (PATHOLOGICAL.)—The term gangrene is loosely applied by the clinician to any form of local death of tissue occurring within the living body, in which the necrosed area becomes discolored, resembling more or less tissues which have been burned. By the pathologist it is used to indicate a necrosis accompanied by putrefactive processes. A number of designations are used partly as synonyms and partly to express different varieties of this condition: mortification, putrescence, putrefaction, sphacelation, etc.; but the essential idea of gangrene is that of necrosis accompanied by putrefaction. The presence of putrefactive or saprophytic bacteria is, therefore, to be regarded as the most distinctive feature of gangrene.

Gangrene may be either *primary* or *secondary*. In primary gangrene the condition is due directly to the infection of the tissues by some specific bacterium and is to be regarded as a specific affection. In secondary gangrene there is first a necrosis due to some other cause with a subsequent infection by putrefactive bacteria. According to its manner of origin gangrene may be *traumatic* or *inflammatory*, and according to its behavior it may be *circumscribed, diffuse, spreading, phagedenic*, etc. Clinically, various forms occur: *thermal, toxic, infectious, neuropathic, diabetic, senile, hospital, idiopathic*, etc..

Primary Gangrene.—A number of specific infections may be included under this head: infection with the Bacillus aërogenes capsulatus, B. œdematis maligni, B. diphtheriæ, B. anthracis, B. coli communis or closely related organisms, and probably a number of other imperfectly known bacteria. Any one of these may produce severe inflammatory processes followed immediately or very quickly by gangrene, which is apparently due to the originally infecting bacterium, though in some cases there may be a secondary infection by saprophytes.

Secondary Gangrene.—This is the more common form. The preceding necrosis may be caused by circulatory changes, pathological conditions of the blood-vessels, burns, freezing, mechanical injury, pressure, corrosive poisons, intoxications, infections, etc.; the secondary infection of the dead tissue being caused by various forms of saprophytic bacteria.

When gangrenous tissues are exposed to the air their fluids may be lost by evaporation and become hard and dry (*mummification, dry gangrene, gangræna sicca*). If evaporation does not occur and the dead parts remain moist, the condition is known as *moist gangrene* (*gangræna humida, sphacelus*). Between the moist and dry forms there is no hard-and-fast line; dry gangrene may develop from a moist gangrene through subsequent evaporation; or by the absorption of fluids from the surrounding tissues a dry gangrene may be converted into the moist form. If the gangrene is very foul-smelling it is usually spoken of as *putrid* or *septic gangrene*. The formation of gas in gangrenous parts gives rise to the condition known as *emphysematous gangrene*. If the tissues affected contained much blood before death, they become black or greenish in color (*black gangrene*); if anæmic, they may remain light in color though always discolored to some extent (*white gangrene*). Clinically *warm* and *cold gangrene* correspond to these forms respectively, the presence of heat depending upon the flow of blood in the neighboring tissue, the warmth being most marked when there is a severe reactive inflammation about the gangrenous area. Black gangrene may become a cold form by the complete shutting-off of the blood supply.

Dry Gangrene.—The evaporation of fluids from the surface of gangrenous tissues exposed to the air gives to the dead part an appearance somewhat resembling that of mummy tissue. The drying of the umbilical cord may be taken as a physiological prototype of this process. Putrefaction goes on very slowly in the dried mass and may cease entirely. Only rarely, however, does mummification of necrosed tissues occur without some putrefactive changes. There is almost always an odor about the parts involved in dry gangrene and this is in itself an evidence of the occurrence of putrefactive processes. The odor, however, is always much less marked than in the case of moist gangrene. Dry gangrene occurs most frequently in the parts of the body most exposed to evaporation; gangrene of the tips of the ears, nose, fingers, and toes is almost always of this variety. The loss of the epidermis is a favoring factor.

In the great majority of cases dry gangrene is due to arterial or venous obstruction through embolism or thrombosis, whenever the collateral circulation is insufficient to keep up the nutrition of the affected part. It occurs frequently after freezing, the peripheral vessels being occluded by thrombi. Severe burns, as well as the effects of strong corrosives, are frequently followed by dry gangrene. It is as a rule found in ergotism and the symmetrical gangrene of Raynaud's disease, and occurs frequently in diabetes and in cases of senility with vascular changes, especially in individuals whose general nutrition is lowered. The fœtus papyraceus is considered by some authors to be an example of dry gangrene, the mummification of the dead fœtus being caused by premature loss of the amniotic fluid and the pressure exerted upon the former by its living twin. In the absence of putrefactive changes this condition can hardly be regarded as being of the nature of gangrene.

Moist Gangrene.—This form occurs very frequently after severe traumatism to the extremities, especially contusions and crushing with resulting great injury to the blood-vessels. It follows obstruction of the venous circulation more quickly than that of the arterial. Diabetic gangrene is not infrequently of this form, senile more rarely so. It may occur in the course of the acute infectious fevers, either in the skin or in the mucous membranes. It forms a feature also of certain skin diseases. Decubitus (bed-sores), malum perforans, hysterical gangrene, noma of the mouth and genitals are varieties of moist gangrene. The internal and external female genitals may suffer moist gangrene from mechanical injury received during severe labor or as the result of infection following childbirth. Of the internal organs the lungs are most often affected. Pulmonary moist gangrene may follow infarction, non-resolution of croupous and purulent pneumonias, inspiration pneumonia, pulmonary abscess, atelectasis, bronchiectasis, new growths, etc. Pressure upon the trachea or bronchi, or upon the branches of the vagus by œsophageal diverticula, tumors or aneurisms not infrequently gives rise to pneumonia followed by moist gangrene. Embolism or thrombosis of the mesenteric arteries with infarction of the mesentery is always followed by moist gangrene. Intestinal obstruction, intussusception, strangulated hernia, obstruction or strangulation of the appendix usually lead to moist gangrene of the affected parts. Traumatic injury to the pancreas or inflammation of this organ from unknown causes may give rise to moist gangrene (gangrenous pancreatitis). Torsion of the pedicle of new growths, floating spleen, kidney, etc., may by shutting off the blood supply cause a necrosis which through secondary infection often becomes gangrenous. Infiltration of the perineal tissues with urine, excessive œdema, extreme passive congestion, are also conditions leading to moist gangrene. Gangrenous inflammation of the urinary bladder may be caused by long-continued retention of urine.

Gross Appearances.—Dry gangrene is usually circumscribed. The affected part becomes discolored, yellow, brown or black, though in rare cases the dead tissues may appear bloodless and pale. The consistence of the part may be hard and tough. In advanced stages the necrotic area resembles leather or mummy skin. An odor of putrefaction is usually present in the early stages, but is never very marked. The process of mummification may be preceded by the formation of vesicles or blebs which rupture leaving the corium denuded. Evaporation is in this way greatly aided. In many cases the skin remains intact, and in this event the amount of putrefactive change may be very slight.

Moist gangrene is characterized particularly by a foul odor and progressive softening of the affected area. The color is usually reddish-purple in the early stages, but later becomes dark brown or black from the changes occurring in the blood pigment. If hydrogen sulphide is formed, the color becomes greenish from the formation of a hydrogen-sulphide compound with the iron-containing blood pigment (pseudomelanosis). Blebs are usually formed in the skin; these contain dirty-brown fluid which derives its color from broken-down blood pigment. Ultimately the entire part affected becomes very soft and partially liquefied. With the growth of putrefactive bacteria in the dead tissues the various phenomena of putrefaction are presented exactly as in the cadaver. Hydrogen sulphide, ammonia, indol, skatol, fatty acids, amins, carbonic acid, and other gases which give rise to the very marked fœtid odors characteristic of this process are formed, and as the result of gas formation a local or widespread emphysema may occur. The fluids arising from the liquefaction of the dead tissues or from the infiltration of lymph are also discolored by the destruction of the blood pigment.

Between the living and dead tissues in both dry and moist gangrene there is usually a more or less sharply marked line of demarcation which represents the point at which necrosis and putrefaction cease. At this boundary line there is very frequently present a zone of inflammatory reaction, particularly in dry gangrene and those forms of moist gangrene due to vascular changes. In other varieties of moist gangrene, particularly in that occurring in diabetes, neither the inflammatory zone nor a sharp demarcating line is present. In advanced stages of moist gangrene sequestration of the dead tissues from the living may occur, and the former either be cast off, absorbed, organized, or calcified, etc. When internal the gangrenous area usually becomes encysted. In hard parts, cartilage, bone, etc., the process of sequestration is much slower than in softer tissues.

Microscopical Appearances.—The differential diagnosis of moist gangrene from other forms of necrosis by means of the microscope depends entirely upon the presence of putrefactive bacteria and the chemical products of putrefaction. Sections of tissues in a state of dry gangrene show a marked shrinking of the cells and disappearance of the nuclei, the changes resembling very much those occurring in the horny layer of the epidermis. If putrefactive changes have been slight, the nuclei may stain faintly, even for some length of time after the advent of necrosis; and the outlines of the cells, though greatly shrunken, may still show. In advanced stages of evaporation the dry tissues become hyaline and horn-like, resisting cutting. In the blood-vessels disintegrated red blood cells are found, often forming brownish or yellow hyaline clumps. If moist gangrene preceded the evaporation, the chemical products of decomposition as well as evidences of greater disorganization of the tissues will be present.

In moist gangrene the tissues show either a simple, cheesy, coagulation, or liquefaction necrosis; or, as is usually the case, all of these forms of necrosis may be present in different parts of the sections. Necrosis of the parenchymatous cells first takes place, the nuclei disappear, and the cells become fluid or granular. Fatty degeneration of an extensive degree is often present. Muscle cells lose their striations, swell, and finally fragment or liquefy. Zenker's necrosis is usually present to a greater or less degree. Adipose tissue and nerve sheaths break up into free fat or fatty acids. Axis cylinders may either fragment or fibrillate. Connective tissue, yellow elastic tissue, fascia, cartilage and bone are changed more slowly, but all tissues may ultimately become liquefied. Hemorrhages are present in the early stages, usually by diapedesis from the early degenerative changes in the vessel walls. Rupture of the damaged vessels may also occur. Disintegration of the extravasated blood takes place, and brown or yellowish granules of hæmatoidin and hæmosiderin are formed from the diffused hæmoglobin. If hydrogen sulphide is present, black granules of hydrogen-sulphide-hæmosiderin are formed (pseudomelanin). Crystalline pigments derived from hæmoglobin may also be present. Fatty-acid crystals, tyrosin, leucin, cholesterin, crystalline and amorphous phosphates and carbonates may be formed as intermediate or end products of the putrefactive process. The coffin-lid crystals of calcium phosphate are often abundant. By means of proper staining methods the presence of putrefactive organisms in large numbers may be demonstrated. If the process has advanced slowly and the reactive inflammation is marked, the dead tissues may contain large numbers of leucocytes which also necrose ultimately, but retain their staining power much longer than the tissue elements. At the line of demarcation there is often an extensive formation of fibrin in the lymph spaces and also coagulation of the blood in the blood-vessels. Beyond this, toward the living tissue there is a more or less well-marked zone of inflammation. If the gangrenous process comes to a standstill, granulation tissue may be formed at the line of demarcation gradually encapsulating the dead area. The latter may shrink away from the border and be cast off as a sphacelus or slough, or it may be gradually disposed of in the slow process of healing by organization. If internal, the encapsulated mass of dead tissue may undergo calcification or liquefy, in the latter case forming a cyst.

Varieties of Gangrene.—In the circumscribed form the line of demarcation shows a zone of marked inflammatory reaction, and the necrosed part is either cast off as a slough or encysted. In the diffusely spreading forms there is no limitation, and the process advances until the death of the individual occurs or the necrosed portion, together with the cause of the gangrene, is removed from the body by surgical operation. In these cases the tissue resistance is either greatly lowered or the poisons produced by the infecting bacteria infiltrate the surrounding lymph spaces causing a spread of the necrotic process, or the bacteria have the power of invading and destroying tissue not previously damaged. In the circumscribed form the infection is less virulent or the surrounding normal tissues are able to resist the spread of infection. In metastatic gangrene bacteria are carried through the blood or lymph and set up secondary foci of inflammation and gangrenous necrosis. This can happen only in the case of primary gangrene, due to infection with a specific organism.

Senile Gangrene.—This is usually of the dry, circumscribed form, and is due almost wholly to disturbed circulation from arteriosclerotic changes, thrombosis, embolism, etc. Chronic wasting diseases, poor nutrition, weakened heart's action, exposure to cold, etc., are favoring factors. The lower extremities, more often the left, are chiefly affected.

Diabetic Gangrene.—The gangrenous processes which occur rather frequently in connection with diabetes are more probably the result of arterial disease than of some more obscure cause dependent upon or associated with the altered metabolism existing in this disease. Wallace (St. James' Hospital) examined twenty-four cases, in twenty-three of which he found decided atheroma. The views most commonly held at present incline toward the belief that gangrene never occurs in diabetes without the presence of arterial changes sufficient in themselves to have caused it. The extremities are chiefly affected and the dry form is more common, but moist gangrene is not infrequent. It has been stated that diabetic gangrene differed from other forms in that no sharp line of demarcation or zone of inflammatory reaction is present. Recent observations show no essential differences between diabetic gangrene and any other form due to arterial obstruction. Cutaneous gangrene, moist gangrene of the lungs, etc., have also been observed in association with diabetes, but must be regarded as coincidences. Favoring factors, such as disturbed nutrition, central nervous disturbances, etc., no doubt exist in diabetes, but the primary cause of the gangrene which occurs in this disease is to be sought in other conditions than the disturbed metabolism.

Gangrene with Acute Infections.—Gangrene may occur as a rare complication of any one of the acute infections, particularly in measles, varicella, scarlatina, diphtheria, typhus, typhoid fever, and malaria. In varicella and scarlatina it usually occurs several weeks after the attack. The gangrene is usually multiple but not symmetrical. The skin and adjacent structures are more frequently affected than the extremities, and usually no previous vascular disturbance is noticed. It occurs more frequently in cachectic children, but also in those apparently in good nutrition. The gangrenous process may affect the eyelids, conjunctiva, ears, mucosa of mouth, lips, and adjacent structures (noma, cancrum oris), external genitalia, particularly those of the female. The term noma has come to be applied to all of these forms, as well as to spontaneous gangrene of these regions occurring without any relation to the acute infectious fevers. It is undoubtedly a specific infection and a number of micro-organisms have been described, but the diphtheria bacillus seems to be the one most constantly present.

Spontaneous gangrene is reported also as occurring in pertussis, acute rheumatism without apparent cardiac involvement, beri-beri, influenza, croupous pneumonia, erysipelas, catarrhal jaundice, and in association with infantile syphilis. In the majority of these cases no bacteriological examination was made, and the exact nature of the process remains unknown. In the case of erysipelas, a number of instances are reported in which gangrene was caused by long-continued application of cold to the affected parts. Under these circumstances the resulting thrombosis of the peripheral vessels is sufficient to account for the gangrene.

Multiple Gangrene.—There are three classes of multiple gangrene:

1. Raynaud's Disease. In this condition there are previously well-marked vascular disturbances in the extremities as shown by syncope, asphyxia, or hyperæmia. The gangrene is often symmetrical, and is usually slight in extent, being confined to the fingers or toes, more rarely to the tips of the ears or nose tip. The disease occurs

chiefly in neurotic and poorly nourished individuals of early adult life. It has been regarded as a gangrene due to trophic disturbances of central origin, but the necrosis is to be looked upon as secondary to vascular phenomena of vaso-motor origin.

2. Multiple Spontaneous Gangrene Occurring in Young and Middle-Aged Individuals without Obvious Cause. These cases of so-called idiopathic gangrene have been reported in large numbers. In very few of them was a bacteriological or pathological study carried out, and it is very probable that the majority were due to vascular obstruction or specific infection.

3. Multiple Spontaneous Gangrene with Acute Infections. Multiple patches of gangrene, not symmetrical, occur as complications of acute infections, measles, typhoid, typhus, scarlatina, diphtheria, and malaria. The skin and adjacent tissues are more frequently affected than the extremities. No previous vascular disturbances have been observed. In typhoid fever the complication of gangrene occurs most often in the male, and is found in order of its occurrence in the left leg, carotid region, mesentery, and cheek. In the majority of these cases an endarteritis is found at autopsy, while in other cases the gangrene seems to result from the toxic action of the products of the typhoid bacillus. Weakened circulation and impaired nutrition are favoring factors.

Neuropathic Gangrene.—In parts of the body affected by sensory or motor paralysis slight injury, such as long-continued pressure, very frequently produces gangrene. This occurrence has been explained as being due to the removal of trophic nerve influence, but it has not yet been conclusively proved that the complete cutting-off of the nervous supply of a part is in itself sufficient to cause gangrene. The cause is much rather to be sought in circulatory disturbances and secondary infections. Raynaud's disease and other forms of symmetrical gangrene have been regarded as neuropathic affections, but are probably dependent upon vascular disturbances.

More properly to be regarded as neuropathic are those cases of hysterical gangrene in which under mental excitement, hysterical crises, or apparently under the control of the will gangrenous areas are formed in the skin. These are usually sharply circumscribed, and are preceded by various vascular phenomena which make it evident that vaso-motor disturbances play the chief rôle in their production. In many of these cases there have been, however, undoubted evidences of fraud on the part of the patient, and it has been shown that the gangrenous areas were self-inflicted and were produced by applications of hydrochloric acid, acetic acid, Paris green, caustic potash, green soap, concentrated brine, or by methods unknown. The gangrenous areas in these cases are irregular, of varying depth of loss of tissue, and do not correspond to the course of either vessels or nerves. The existence of true hysterical gangrene cannot be regarded as an impossibility, but it is to be explained on the hypothesis of vaso-motor disturbances and not as evidence of removal of trophic influence.

Lepra mutilans, noma, acute decubitus, etc., have also been regarded as examples of neuropathic gangrene, but the majority of conditions so considered have been found to depend upon vascular and nutritive changes or specific infection. Multiple gangrene of the skin is also said to occur in excessive iodism, and it is probable that some of the supposed hysterical cases may be explained by this fact.

Traumatic Gangrene.—This is frequently produced by rupture of the inner arterial coats. Simple contusion over an artery without injury to the skin may cause rupture of the inner coat with resulting thrombosis and gangrene. Circumscribed rupture of the inner coat occurs especially in the case of fractures. The intima may be rolled up within the vessel blocking the lumen. Dislocations, especially those of the shoulder joint, through injury or compression of the vessels may cause gangrene secondary to thrombosis. In severe trauma with resulting disorganization of the tissue gangrene results from secondary infection of the dead part. In the case of open wounds without destruction of tissue primary gangrene may be caused by direct infection with specific bacteria.

Hospital Gangrene.—This form of wound gangrene, so common and so disastrous in its results during the Civil War, has practically disappeared. It represented a specific infection, the cause of which is not known.

Emphysematous Gangrene (Gangrene Foudroyante, Gaseous Cellulitis, Gas Phlegmon, Infective Emphysema, etc.). In gangrene with gas formation the Bacillus aërogenes capsulatus is the most commonly occurring specific cause. The colon and proteus bacilli are doubtful factors. Facultative anaërobic bacilli resembling colon bacilli may produce the condition, and other forms of bacteria have been described as causal agents, but their exact relation to the process is not clear. The B. aërogenes capsulatus is widely distributed in soils, dust, etc., and is present in the intestine and probably in other parts of the normal living body. Gaseous gangrene may also be produced by infection with anthrax and malignant œdema, but it is probable that some of the cases regarded as malignant œdema in the human body were in reality cases of infection by the B. aërogenes capsulatus.

The organism enters through open wounds, particularly those associated with contusion; but may follow ligation of arteries, or the avenue of infection may be through the uterus after abortion or delivery. The infection is very virulent; at the point of entrance there is a rapid necrosis with gas formation. The entire surface of the body may become emphysematous. At autopsy the internal organs have a characteristic sponge-like appearance from the formation of numerous small gas bubbles throughout the tissues. In these numerous bacilli may be found. The blood in the heart and great vessels is foamy. It is probable that some of the cases of supposed air embolism are due to infection with this organism. The presence of gas cysts or foamy blood in the cadaver several hours after death cannot be regarded as of great pathological significance, inasmuch as this organism, which is probably frequently present in the normal body, may develop under favorable conditions with great rapidity in the dead body.

Toxic Gangrene.—The most familiar form of gangrene due to poisons is that produced by ergot. The ends of the extremities are chiefly affected, the gangrene is usually of the dry form, and is caused by the action of the ergot in producing contraction of the peripheral vessels with thrombosis. Sloughing gangrene of the endometrium, bladder, and skin may also be produced by long-continued medicinal use of ergot.

Roentgen-Ray Gangrene.—Gangrenous dermatitis has followed prolonged exposure to *x*-rays. The condition develops several weeks after exposure and is slow in healing. The exact relation of these cases to the alleged cause is not yet apparent.

Carbolic-Acid Gangrene.—Dry gangrene has been produced in a number of cases by prolonged application of carbolic-acid dressings, even when weak solutions were used. The fingers and toes were the parts affected in the majority of cases; in one instance the eyelids were injured.

Gangrene of Pancreas.—Traumatic injuries of the pancreas or inflammatory conditions of this organ may lead to gangrene. Self-digestion by the pancreatic juices is probably the first step in the process, infection from the intestine the second. Fat necrosis is usually present.

Idiopathic Gangrene.—According to recent observers the so-called idiopathic gangrene occurring in children is always secondary to arterial thrombosis. In the new-born it is frequently associated with congenital syphilis. Gangrene of penis and scrotum in the new-born has been observed a number of times in connection with thrombosis of the renal and spermatic veins. The cause is unknown. In the adult gangrene of the same region occurs from primary infection, or rarely as the result of embolism or thrombosis. The gangrene of the extremities observed in cases of premature labor is probably due to thrombosis or possible primary infection.

Sequelæ.—Besides the end products of decomposition mentioned above, ptomaïns are produced in the gangrenous area. These are for the greater part diffusible and readily absorbed into the circulation, producing the systemic effects of gangrene. The intensity of the general symptoms in any case will depend upon the amount and character of the poisons produced in the gangrenous tissues, the amount and rapidity of the absorption, and the resistance of the patient. The intoxication may be so severe as to cause death, or the gangrene may progress until death is brought about by the involvement of vital parts, or the gangrenous area may become circumscribed, be cast off as a slough, or organized, calcified, or encysted. Portions of dead extremities may drop off spontaneously, or through operative procedures the gangrenous portion may be removed. *Aldred Scott Warthin.*

GANGRENE. (SURGICAL.)—The term gangrene, and its synonyms, mortification and sphacelus, are employed by the surgeon to denote the death and, in most cases, the subsequent decomposition of a circumscribed portion of tissue on some exposed part of the body. Necrosis is a term extensively used by surgeons to denote the death of a circumscribed portion of bone, whilst pathologists employ it to express the death of a portion of tissue, belonging to some internal organ, that has been cut off from its necessary blood supply. Such necrosis is unaccompanied by bacterial decomposition; it is absorbed and replaced by the formation of blood-vessels and new tissue.

ETIOLOGY AND PATHOLOGY.—A general division of the causes of gangrene into traumatic, physical, and infectious may be made, but it is evident that, whether the local death of a part is produced by mechanical violence or by other causes, the result must be the same—namely, an interference or arrest of the nutrition of the part due to obstruction of the circulation. Nutrition is interfered with, or arrested, by *obstruction in the arteries*, such as occurs in cases of gunshot wounds; by ruptures due to mechanical violence; by compression or ligature; by disease of the arterial coats; by pressure of a tumor in the adjacent tissues, or by a thrombus; by *obstruction in the capillaries*, which may produce complete anæmia of the part, and which is due to pressure upon the capillary walls by tumors, by extravasated blood or fibrin, or by superficial pressure from bandaging. The observation that tight bandaging would occasionally produce gangrene is as old as Hippocrates, who distinctly refers to it. Anything, therefore, which will produce long-continued stasis in the capillary circulation of a part,—whether it be mechanical violence, inflammatory change, the internal administration of certain drugs, the action of chemicals, or some obstruction in the veins sufficiently pronounced to prevent completely the return circulation,—must necessarily result in gangrene of that part.

Let us now examine these causative states somewhat in detail. Obstruction to the arterial circulation occurs in consequence of gunshot, lacerated, and incised wounds, whenever the artery is torn or cut, and this obstruction results in gangrene whenever the collateral circulation fails to become established. The plates accompanying this article, from the "Medical and Surgical History of the War of the Rebellion," show cases of this kind with great distinctness. Pressure upon arteries during the treatment for aneurism has also produced gangrene. Surgeon Fessenden, of the Marine Hospital Service, has reported a case* in which compression was applied to the popliteal artery, just above an aneurism of that vessel, for one hour, when pulsation ceased in the tumor; three days later, it was noticed that sensibility was lost in the foot and leg, which became very much discolored, and there occurred blebs on the foot; a day later the entire foot and leg were gangrenous, and amputation was performed.

Coagula (*thrombi*) may form in the arteries as a result of chronic endocarditis or endarteritis. Obstruction to the capillaries is a prolific source of gangrene. It is in them that the effect of diminished cardiac power is most manifest, especially in the parts remote from the heart. Chronic exhaustive diseases, senile and general debility, therefore, are important factors in the production of gangrene. Gangrene from the administration of ergot is produced by the effect of the drug on the arterioles through the vaso-motor nerves, whereby these vessels are permanently diminished in calibre. The experiments of Holmes (1870) showed the effect of ergot upon animals to be manifested in the capillaries, as witnessed in frogs, and Péton (1878) observed the contraction of the retinal vessels in man. Péton believes that this effect is produced, independently of any influence upon the vaso-motor system, by the direct action of the drug upon the muscular fibres. Nikit, however, in 1878, denied this, and his investigations have led him to confirm the usually accepted theory. In recent years we have learned to distinguish some infectious causes of gangrene, and also to recognize the fact that carbolic-acid solutions are, in certain cases, competent to induce this condition. Farther on, we will consider these matters more in detail.

Ergotism, as a cause of certain epidemics of gangrene in man, was first described by Dodard in 1676, then by Saviard in 1694, and by Noel in 1710. The disease appeared in Switzerland in 1676, according to Langius and Quassond. It also appeared in Dauphiné in 1709. Duhamel, in the "Mémoires de l'Académie Royale de Paris" for 1748, states that the disease was accompanied by very great mortality, "not more than four or five out of one hundred and twenty who had been attacked escaped with life." Péreira (1840) thinks that this affection was known at a still earlier period, and he quotes a passage from Sigebert to support his views (South): "1089, a pestilential year, especially in the western parts of Loraine, where many persons became putrid in consequence of their inward parts being consumed by St. Anthony's fire. Their limbs were rotten and became coal-black, they either perished miserably or, deprived of their hands and feet, were reserved for a more miserable life." It is stated that "the bread which was eaten at this period was remarkable for its deep violet color."

Notwithstanding the general concurrence of opinion as to the effects of ergotism on man, it has often been denied that it produced any such effect upon animals. Block, in 1811, fed nine pounds of ergot daily to twenty sheep for four weeks without any visible effect, and twenty sheep of another lot ate thirteen and a half pounds daily for two months without injury. Thirty cows took twenty-seven pounds daily for three months, and the only apparent effect was to injure the quality of the cream (Péreira). Tessier, however, in 1776, visited those countries in which the epidemic had prevailed, or was then present, and found that, although the quantity necessarily varied, yet it finally produced the gangrenous affection ("Mémoires de la Société Royale de Médecine," 1776, 1777–78). Instances are not wanting of the prevalence of gangrene as an epidemic among animals in the United States. Dr. Salmon, Chief of the Bureau of Animal Industry of the Agricultural Department, in a recent report on this subject (1885), has shown conclusively that many so-called epidemics of the "hoof-and-mouth disease" of cattle are really epidemics of ergotism. He found much ergot in the heads of "red-top" grass, in timothy, and in the chess or "cheat," as well as in rye; and in the particular epidemic in Kansas which called out the inquiry, the ergot was found in the hay fed to the diseased animals in the proportion of about one to every seventy-five pounds. In these cases there were sloughing ulcers of the mouth, ulcers in the rectum, with diarrhœa, a temperature of 101° to 104° F., and a line of demarcation above the hoof in some cases as high as the middle of the leg, and not infrequently the ends of the tails became gangrenous and dropped off. In an exhaustive review of the history of epidemics of gangrene from ergotism, Dr. Salmon cites many instances to show that nearly all the domesticated animals have suffered from the effects of this poison. As bearing upon the question of treatment, it is interesting

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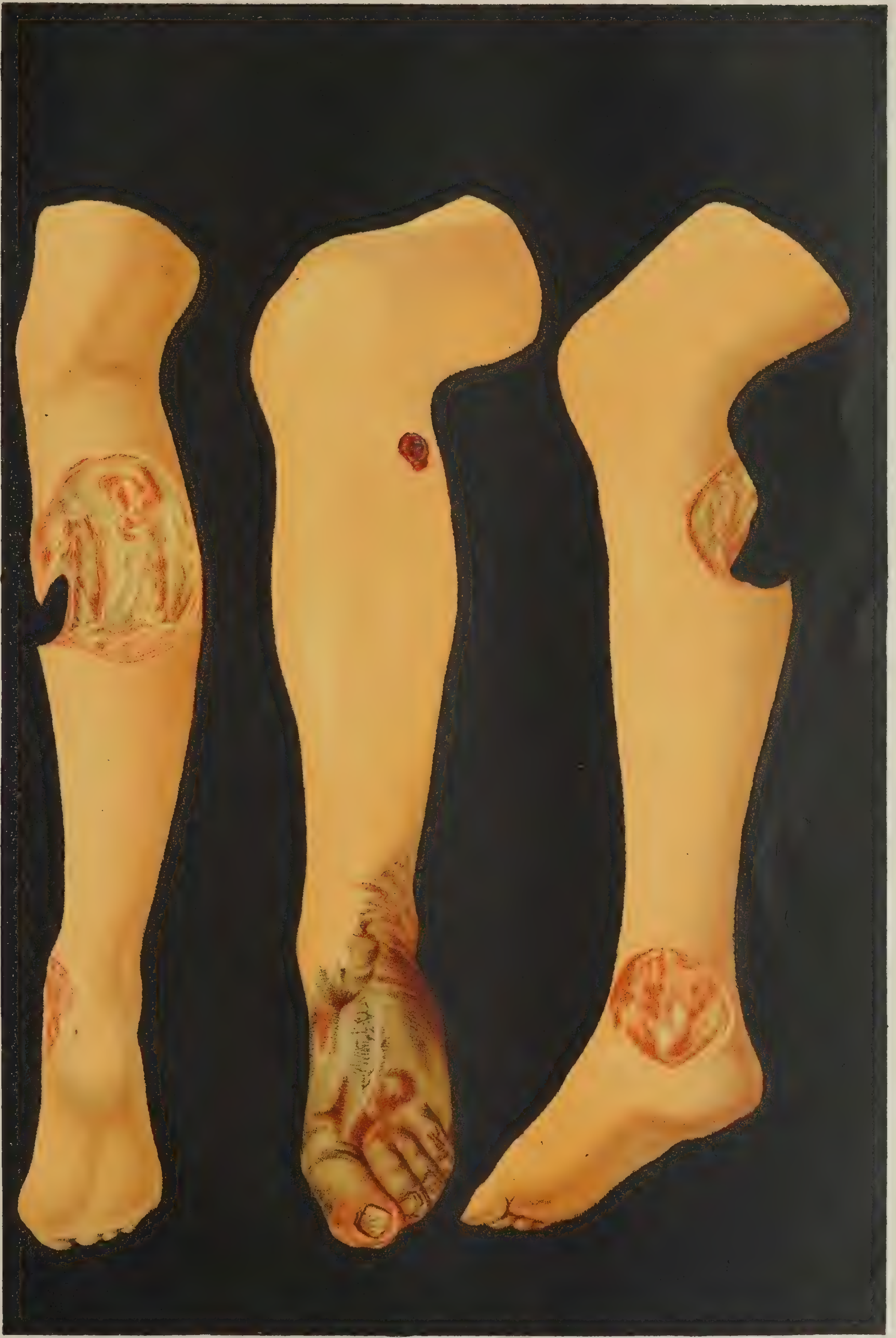
*U. S. Marine Hospital Reports, 1882, pp. 160–162.

PLATE XXIX



FIGS. 1 AND 3 SHOWING EFFECTS OF HOSPITAL GANGRENE.
FIG. 2 GANGRENE OF FOOT AFTER SHOTWOUND OF LEG.
(FROM THE MEDICAL AND SURGICAL HISTORY OF THE WAR OF THE REBELLION.)

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to note that Dr. Salmon considers that ergot in hay may be prevented by cutting the grass before the seeds have formed.

The first effect of extreme cold upon the tissues is the contraction of the capillaries to the smallest practicable degree. A certain amount of blood serum is actually frozen and the capillary is ruptured, the circulation is not resumed when the parts are thawed, and gangrene results. Gangrene thus produced is usually of the dry variety, although, when the venioles or the larger venous trunks are frozen, by reason of the failure of the return circulation, moist gangrene is produced. Direct destruction of cells by caustic chemicals may produce gangrene of distal parts, through failure of both supply and return of blood. Gangrene of the perineum may occur from extravasated urine (Green, 1884), as even normal urine is highly irritating; but in such cases there must have been local inflammation and consequent death of the adjacent cells. Urine which has undergone putrefaction, being loaded with the putrefactive bacteria, is often very speedy in its action, especially as the tissues themselves are weak in their power of resistance; while not absolutely devitalized, they are yet in a state of extreme inertia. It is well known that the power of resistance to the entrance and subsequent development of the pathogenic bacteria is variable, and that, for instance, in cases of convalescence from such exhaustive diseases as typhoid, typhus, and the severer exanthemata, fatal forms of so-called blood-poisoning are apt to make their appearance; this condition, while perhaps immediately dependent upon diminished cardiac power, is one of deficient innervation; for insufficient nutrition of the nerve centres is necessarily manifested in weakness of muscular tissues throughout the body.

Obstruction of the veins, it will be seen, is very rarely a direct cause of gangrene; pressure or occlusion of the superficial veins alone will scarcely produce it, unless there is constitutional predisposition, as above set forth, for the deep veins will still carry away a large share of the return blood current. When gangrene does result from compression or ligature of superficial veins, it is by the production of stasis in the capillaries; to this cause we must refer the cases produced by tight bandaging, and, indeed, all of similar character, except those of venous thrombi.

Moist Gangrene.—This form of gangrene, also called acute gangrene, hot gangrene, inflammatory gangrene, is always preceded by inflammation. The part is at first swollen and painful, there is almost always inflammation of the veins (phlebitis), and the moist condition depends upon the obstruction to the return circulation, by which the water is left in the tissues.

Symptoms.—There will be a history of an injury and of antecedent inflammation, and there will be an absence of pain in the part that is actually gangrenous, although the adjacent parts, where the inflammatory blush is present, will be the seat of acute pain. Characteristic changes in color will take place; the part will be at first livid, then bluish, and finally completely black. Then, again, there will be swelling of a boggy character (œdematous), sometimes accompanied by emphysematous crackling. It is sometimes said that sensation is not destroyed; but this, when seemingly present, is only the well-known phenomenon of a person's experiencing, in a wounded or severed nerve, sensations which he refers to the peripheral area of distribution of that nerve. In the beginning the odor is imperceptible, but as the putrefactive change progresses the odor becomes "sweetish," and finally stinking in the highest degree. Constitutional symptoms of toxæmia are usually present, and in advanced stages of this condition great prostration is noted, even collapse; diarrhœa may be present, and in exact proportion to the degree of fever there will be the profound rigors and profuse sweatings of pyæmia; but if the gangrene is not extensive and is well localized, there may be little general disturbance. In cases in which the disease is protracted, the septic fever pursues its usual course, and the well-known typhoid condition of the system will be present, the various symptoms of which need not be here described.

There is little difficulty in the *diagnosis* of this affection, but in the lax condition of the skin of the aged, with its enfeebled circulation and diminished vitality, there is sometimes doubt whether the blackness of the surface is due simply to ecchymosis or to gangrene. When the gangrene ceases to advance there is usually seen, encircling the part, a series of vesicles, or sometimes a mere line of redness. This redness becomes deeper, the epidermis over it falls off, the dead part begins to shrink away, and nature commences, by the rapid consolidation of the inflammatory exudate, to prevent further absorption of any septic material by the lymphatics. This line of redness (termed the "line of demarcation") is a narrow band of granulation tissue, which, like all granulation tissue, is characterized by the absence of lymphatics, and hence is incapable of absorbing septic material. The line of demarcation gradually extends entirely to the bone, in case an extremity is involved, and the dead soft part finally drops off. So long a time is required for the bones to undergo this process that they are usually seen protruding, and the case is seldom left to nature beyond this point.

Treatment.—When gangrene is threatened the treatment should be directed toward its prevention; *i.e.*, the inflammation should be combated, and the return circulation favored by massage and external heat. There is no single remedy so generally applicable and so prompt in its effects as external heat. The part, after gentle friction, may be enveloped in hot flannel, which should be changed frequently, or bottles of hot water may be applied. Another plan, which is preferred by some, is to irrigate the threatened part with hot water. But if this plan is adopted, it is necessary, if any good is to be accomplished, that the water used shall be as hot as can be borne. Thus the feeblest circulation may often be encouraged so that it once more becomes strong, and the effect of these measures in keeping alive the collateral circulation in cases in which the main artery is occluded from injury, operation, or disease is often beneficial in the highest degree. The old axiom that "heat is life, and cold is death" is nowhere more applicable than in these cases. When stasis is manifest by the presence of œdema, and by the boggy feel of the tissues, broad punctures, made deeply through the tissues, are of great service. The patient should be supported with tonic and stimulant remedies according to individual judgment. When the gangrene has become complete, local remedies are of no avail except to favor the production of sloughs, to hasten their separation, and to render the odor less offensive. Among these may be mentioned solutions of bromine, Labarraque's solution of chlorinated soda, and solution of the bichloride of mercury. The mass can be rendered quite innocuous by deep injections of the bromine solution. When the line of demarcation is fully established, operative interference is then demanded.

Dry Gangrene.—In this form of gangrene there is neither venous obstruction nor failure of the lymphatics, and the fluids of the part are carried back into the system as fast as formed. As the arterial supply is gradually cut off, a drying or mummification of the tissues results. This condition frequently occurs in those who are suffering from starvation or who are subject to gout (Chelius); it also occurs in those who have exhausted themselves by excessive debauchery. There is frequently an absence of inflammatory symptoms, and the gangrene may develop suddenly without premonition. There is usually organic disease of the heart and arteries. This is the chronic gangrene of Travers (South).

Symptoms.—Corrugation and shrinking of the soft parts, and gradually deepening color, until the whole mass is of a coal black; pains of varying severity usually precede the discoloration, sometimes lasting for several weeks. Occasionally pain is absent, and the patient simply experiences a sensation of coldness and numbness in the part. As the gangrene progresses, constitutional symptoms are manifested, there are great mental depression, unquiet sleep, palpitation of the heart, epigastric pain, and occasionally an intense internal cold (Chelius). Sometimes the distinctive characteristics between dry and moist gangrene are so obscure that it is difficult to place the case in one class or the other (Moore: "International Encyclopedia of Surgery," 1882).

The *treatment* is essentially the same as that already recommended for the moist form of the disease.

The *prognosis* is unfavorable.

SENILE GANGRENE.—This gangrene, which is usually of the dry variety, is almost wholly due to arterial obstruction, the pathology of which has already been discussed; but the obstruction is long in forming, and the progress of the disease is slow. The description which Percival Pott gave of the affection, as it occurs in the foot, was so striking that for a long time it was known as Pott's disease of the toe; but, as the disease occasionally attacks the hands, the name was manifestly inappropriate. The condition of the arteries in these cases is one of "ossification," or, rather, of calcification, which results in a complete loss of elasticity of their walls, and consequent diminution of the blood supply. The bead-like feel of the radial pulse, in the aged, gives the observer a palpable object-lesson in senile calcification. The statement has been made that certain seasons specially predispose to senile gangrene, and the winter is alleged to be the season most favorable to its production, owing to the astringent effect of the cold; but there are no statistics to bear out this assertion, and the writer considers the case by no means made out.

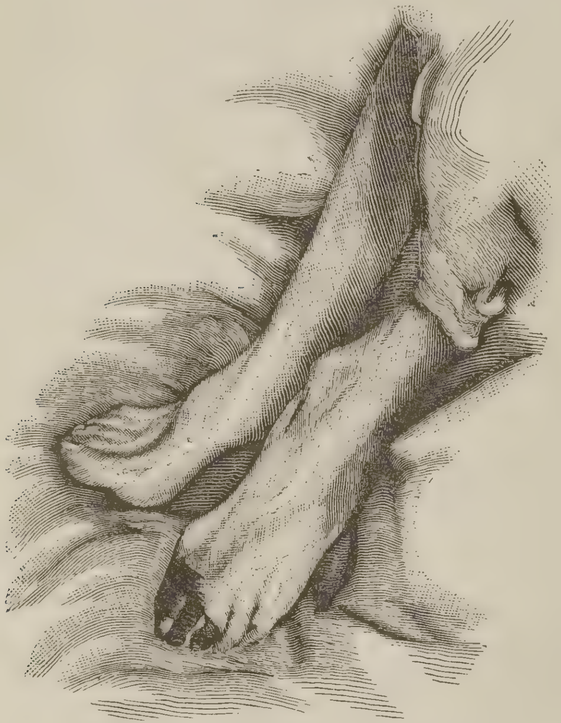


FIG. 2267.—Dr. Hamilton's Case of Senile Gangrene.

Symptoms.—After some months or weeks of pain or otherwise unpleasant sensations in the part, a small bluish spot appears on one of the toes, frequently at the root of the nail, and the spot becomes black; from this point the discoloration slowly spreads to the adjoining toes, and finally, if the patient survive long enough, the whole foot and leg become involved. Sometimes the line of demarcation is formed near the centre of the foot, but more often the patient succumbs under the combined influence of the nervous exhaustion produced by the pain and of the failure of the digestion. The pain accompanying the disease is a prominent symptom, and gives the patient more immediate concern than the fear of losing the limb, or even life itself. The accompanying figure, taken from a photograph of a patient under the care of Dr. John B. Hamilton, at the Providence Hospital, shows the stage of the disease at the time of her death. The notes are as follows: Elizabeth B——, aged eighty-five, admitted to hospital April 13th, for a contusion of the knee, which, however, had left no trace; the pain in the toes and foot had been constant and harassing. Three weeks later, a blue spot was noticed on the dorsum of the second toe. The spot gradually spread until it included the great toe, as shown in the photograph, and the patient died July 20th, 1885.

Treatment.—This has been well formulated by Van Buren. "The treatment of senile gangrene is limited to a judicious husbanding of the patient's vital resources, looking to a possible self-limitation of the disease, after which a cure may be completed by amputation." To husband the patient's resources it is necessary, along with stimulating and supporting measures, to control the pain; here there is nothing more philosophical in its action than the hydrochlorate of cocaine injected into the painful tissue. In these cases, as in the foregoing varieties of gangrene, external heat will be found advantageous.

SYMMETRICAL GANGRENE (*Relapsing Gangrene*).—This affection, probably first accurately described by Raynaud ("De l'Asphyxie locale et de la Gangrène symmétrique des Extrémities," 1862), is exceedingly rare. According to Raynaud, the disease occurs chiefly in chlorotic and nervous individuals of early adult life, patients in convalescence from typhoid fever and similar exhausting disease. Moore ("International Encyclopedia of Surgery") has seen a case presumably dependent upon this cause, and the appearance of the parts affected is shown in the plate which accompanies the doctor's article.

"The disease most frequently attacks the fingers—rarely the toes, tip of the nose, and external ear; often, for months beforehand, the affected parts suddenly become white, bloodless, without feeling, dead; the skin is strongly wrinkled and shrunken, the ends of the fingers appear thin and conical. The temperature of the parts is sunken, and the muscular movement is as though paralyzed. If this state extend over a whole extremity, the pulse becomes imperceptible. After a variable time there follows a painful reaction; itching arises, and the feeling of overfilling of blood; the skin becomes bluish-red. Severe pains precede the proper outbreak of gangrene. The extremities become bluish-white, violet, dark, livid, marbled; they are insensible but very painful, and icy cold; then small vesicles appear which fill with sero-purulent liquid, and are usually destroyed, so that the cutis becomes laid bare. Even now, the part may be restored; but for the most part, after a time the attack returns, and then the fingers show numerous small, white, depressed, and hard cicatrices on their extremities, which are found specially in front of and beneath the nails, and form conical callosities. If the ischæmia is of longer duration, there follows from the consecutive hyperæmia a true mummification, which terminates with the falling-off of the last phalanx" (Wagner).

DIABETIC GANGRENE.—The impoverished condition of the blood in cases of diabetes mellitus favors the production of gangrene, and it has been specifically named as a variety, although without any very good reason. As well might gangrene occurring in the progress of any chronic disease be separately named, and in most articles on the subject of diabetes the occurrence of gangrene is mentioned as among the complications of that disease.

"Spontaneous gangrene of the lower extremities, with obstruction of one or more arteries of the limb, is not infrequent in diabetes" (Marchal de Calvi). "Ulcerated surfaces are slow to heal, and gangrene supervenes sometimes spontaneously, but more often as the result of some trifling injury" (Tyson: "Pepper's System of Medicine," vol. ii.). The treatment of gangrene, when it occurs as a complication of diabetes, does not differ in any striking respect from that which is suitable for other types of gangrene or for diabetes when not accompanied by this complication.

Gangrene Due to Infectious Causes.

Diphtheritic Gangrene.—This form is usually named as one of the varieties, but, like the last mentioned, it has no valid claim to be considered a distinct affection. By some, indeed, it is regarded as gangrenous diphtheria, by others as a variety of hospital gangrene. Diphtheritic patches resulting in gangrene are sometimes seen in the edges of the sore resulting from the incision in tracheotomy; and when hospital gangrene is present in a hospital ward, wounds are frequently seen with the tough, fibrinous diphtheritic patch springing therefrom. In these cases the constitutional poisoning seems more severe. This form of gangrene is due to infection by the Klebs-Löffler bacillus, which is known to be the specific cause of diphtheria; and the constitutional disturbance which is referred to as a characteristic feature in these cases is, doubtless, the result of the profound toxæmia that always accompanies diphtheria.

The *treatment* of diphtheritic gangrene is the same as that of hospital gangrene, which will be mentioned in detail.

Noma.—This is a gangrene affecting the pudenda and cheeks of young children from the age of weaning to that of puberty. Nurslings seem to have an immunity from it. When confined to the cheeks and mouth, it is variously termed *gangrenous stomatitis, gangræna oris, cancrum oris, gangrenopsis-stomato-necrosis, necrosis infantilis, buccal anthrax, water canker, sloughing phagedæna* of the mouth, and by the Germans *Noma* and Wasserkrebs; by the French *gangrène de la bouche.* The disease has been known for a long period, and was first described by Carolus Battus, of Amsterdam. Van Swieten (1699) recognized the disease as grangrene. Wiseman (1676) mentions the disease as noma, which he describes as "a deep Ulcer that eats and spreads without Tumor, but hath a Rottenness and Putrefaction joined with it."

The disease is attended by great mortality, but as it usually comes on while the patient is suffering from some other affection, it is difficult to determine its relative fatality with precision. The affection, whether it appear on the cheek or on the vulva, is almost invariably unilateral. It begins as an inflammation attended by great exudation, ulceration is set up, the exudate dies, and the general appearances of circumscribed gangrene due to obstruction of the arterioles are present. In the mouth the disease usually begins at the frenum of the lip, but rarely on the outside of the cheek (Chelius), and as the œdematous inflammation extends the ulcerative process is carried down to the bone and alongside of the nose, and frequently involves the whole Schneiderian membrane. Occasionally the disease begins on the gums at the alveolar border (Cohen). At the pudenda the disease usually commences at the labial margin, and extends to the clitoris, nymphæ and hymen, and sometimes to the urethra, when the pain on micturition is acute; the inflammation is rapid, and the tissues speedily fall out by sloughing, the disease spreads to the perineum, to the anus, the thigh, and to the mons veneris, and, as is the case when the disease affects the mouth, the sloughing is deep and frequently extends quite to the bone. Sometimes the affection beginning at the mouth is later on developed at the vulva, and frequently the noma is ushered in with general constitutional symptoms, such as rigors with fever; but more commonly its onset is masked by the particular affection from which the child has been suffering; but always, in the later stage of the affection, there is great prostration, with feeble pulse and chlorotic countenance. When the affection is on the pudenda, there is great pain in all movements of the lower extremities, and the child usually assumes of its own accord the dorsal decubitus, and the legs are widely separated. There are retention of urine, owing to the severity of the urethritis, and constipation. There is rapid emaciation, and the patient sinks under the "typhoid condition" so constantly present in the later stages of the other forms of gangrene. Cohen remarks that in noma of the mouth pulmonary gangrene is often observed as a complication, as is also enterocolitis. When noma affects the mouth alone, there is great variability in the degree of constitutional sympathy, some patients being able to sit up and play, while others are hopelessly comatose from the outset. Hemorrhage from the facial or from the pudendal branches of the pubic may occur; but in this variety, as in other forms of gangrene, the arteries are plugged by septic thrombi long in advance of the loss of tissue. The disease in most cases is more than likely due to a long thread-like organism of the leptothrix type which has so far resisted cultivation on ordinary media.

The *treatment* of noma is both local and constitutional. For the local treatment such measures should be adopted as are likely to arrest the advance of the disease into sound tissue, and to this end nothing suffices but the application of the most decisive escharotics like the Paquelin cautery or fuming nitric acid. Quinine and iron, stimulants in the form of milk punch and liquid food are always indicated; when the stomach becomes irritable, nutritive enemata should be employed.

Hospital Gangrene.—This form of gangrene, known also under the various names of *hospital phagedæna, gangræna nosocomialis, and pourriture des hôpitaux,* was the scourge of military hospitals in the pre-antiseptic era. To-day it is absolutely unknown, the vast majority of living surgeons having had no clinical experience with it. Whether its spread was due to the agency of a specific micro-organism, or to an acquired virulence of the well-known pathogenic microbes in victims rendered specially susceptible by lowered vital resistance, remains a matter for speculation. Because of its great rarity we must turn to the writings of the older authors for a clinical picture of the disease. Mr. Guthrie graphically describes it as follows: "A wound attacked by hospital gangrene in its most concentrated and active form presents a horrible aspect after the first forty-eight hours. The whole surface has become of a dark-red color, of a ragged appearance, with blood partly coagulated, and apparently half putrid, adhering at every point. The edges are everted, the cuticle separating from half to three-fourths of an inch around, with a concentric circle of inflammation extending an inch or two beyond it; the limb is usually swollen for some distance, of a white, shining color, not peculiarly sensible except in spots, the whole of it being œdematous and pasty. The pain is burning and unbearable in the part itself, while the extension of the disease, generally in a circular direction, may be marked from hour to hour; so that in from another twenty-four to forty-eight hours nearly the whole of a calf of a leg, or the muscle of a buttock, or even the wall of the abdomen may disappear, leaving a deep great hollow or hiatus of the most destructive character, exhaling a peculiar stench which can never be mistaken, and spreading with a rapidity quite awful to contemplate. The great nerves and arteries appear to resist its influence longer than the muscular structures, but these at last yield; the largest nerves are destroyed, and the arteries give way, frequently closing the scene, after repeated hemorrhages, by one which proves the last solace of the unfortunate sufferer. . . . The joints offer little resistance; the capsular and synovial membranes are soon invaded, and the ends of the bones laid bare. The extension of this disease is in the first instance through the cellular structures. The skin is undermined and falls in, or a painful red and soon black patch is perceived at some distance from the original mischief, preparatory to the whole becoming one mass of putridity, while the sufferings of the patient are extreme."

The surface of the wound soon becomes a sticky, pulpy mass of a grayish color. This substance cannot be wiped off, and it resists the usual washings. If, at this stage, the further progress of the disease be not arrested, the patient succumbs, as from a fatal form of septicæmia. The disease was very prevalent in the military hospitals of our Civil War; an extended account of it may be found in the surgical volumes of the "Medical and Surgical History of the War of the Rebellion," by Otis (see Plate XXIX., Figs. 1 and 3).

Treatment.—The treatment should be prophylactic, constitutional, and local. The first of these should have reference to the rules of antiseptic and aseptic wound treatment and to the rules of hygiene that bear on the subject of overcrowding; and when the disease first appears in the wards containing other wounded, it is important promptly to isolate those who are affected. The constitutional treatment should be directed to the free use of stimulants and good nutritious food. The local treatment directed to the gangrene when it invades the wounds should be of the most radical kind. The sloughing tissues should be removed by means of the curette and scissors, and the actual cautery should be applied freely. Bromine, fuming nitric acid, and subnitrate of mercury were extensively and successfully used by the older surgeons.

Malignant Œdema is one of the forms of gangrenous inflammation due to the invasion of a wound by the bacillus of malignant œdema. The organism morphologically resembles the Bacillus anthracis, though it differs from it in being motile, and in that it is strictly anaërobic. It is mostly found in rich garden soil, from which it is isolated by inoculation into animals. It is apt to invade all kinds of wounds—incised, lacerated, punctured. Instances are given of the disease following the sting of insects and penetration from a hypodermic needle. Malignant œdema is regarded as one of the most fatal forms of gangrene. The changes in the tissues are very rapid, a circumstance that led French writers to adopt the name gangrène foudroyante. The changes in the tissues are marked by an abundant exudate and by the formation of gas, both of which exert pressure upon the surrounding blood-vessels, and thus favor the development of gangrene. The clinical picture is best described by Park as follows: "Malignant œdema is known by the brownish discoloration of the overlying skin, which is streaked with blue where the overfilled veins show through it, while the underlying tissues are sodden with fluid and more or less blown up by the gaseous products of decomposition, so that the finger detects a firm crepitus, as is common in subcutaneous emphysema. From the wound, if one there be, flows a thin, foul-smelling secretion, which may also be expressed from the deeper layers. That the neighboring lymph spaces and nodes are actively involved is evident from the enormous swelling of the latter, as well as from the general condition of the patient. The rapid elevation of temperature with but trifling remissions remains constant until shortly before death. The tongue early becomes dry and cleaves to the palate, its surface being covered with a thick, foul fur. Patients early become apathetic, complaining only of pain and burning thirst. Delirium and coma usually precede death, which may occur in even so short a time as from fifteen to thirty hours. After death the cadaver bloats quickly and putrefaction goes on with amazing rapidity."

Treatment.—The treatment of this decisive form of gangrene should be of the most radical character. When the disease is recognized in a wound on a limb, the member should be amputated at once well above the limits of the disease. In situations where amputation cannot be practised, excision of the affected tissues should be practised at once and the wound dressed with antiseptics. The strength of the patient should be maintained by stimulants, nutritious diet, and supporting treatment.

Spreading Traumatic Gangrene.—The last of the infectious forms of gangrene to be noted is known under the names of spreading traumatic gangrene, fulminating gangrene, or gangrenous emphysema. It results most generally in cases of rupture of the principal vessels supplying a part of a limb, with sudden arrest of the blood supply; or in those cases of traumatism in which intense, rapidly spreading inflammation appears. In either condition the rapid death of the part and the spread of the disease process to contiguous healthy structures are due to the sudden development of a mixed infection by micrococci and bacilli. The putrefaction set up by these micro-organisms is often accompanied by the liberation of gas, the presence of which is noted by emphysematous crackling in the subcutaneous tissues as the process spreads beyond the diseased area. As a result of the sudden development of bacterial decomposition, poisoning by ptomaïns, with constitutional symptoms of profound toxæmia, is early noticed. The treatment in such cases demands prompt amputation of the limb implicated, at a safe distance within the sound tissues; or rapid and thorough destruction of all gangrenous parts with the curette and actual cautery, in those situations which do not admit of amputation. (See Plate XXIX., Fig. 2, and Plate XXX.)

Ainhum.—This is a form of gangrene of unknown origin, more frequently seen in men than in women. It has been met with in the East and West Indies, but it is more frequently observed among negroes on the west coast of Africa. The affection is usually limited to the little toe, although it has occasionally been observed in the little finger. It begins by the occurrence, on the plantar surface, of a fissure which encircles the toe near the web. As the fissure deepens, gangrene of the soft parts occurs, with a rarefying osteitis of the bones. The disease is very gradual, the process lasting as much as ten years in some instances. It usually ends in spontaneous amputation.

Carbolic-Acid Gangrene.—The watery solutions of this antiseptic drug used in surgical practice have been known to cause gangrene when persistently applied, especially to fingers and toes. The evaporation of the water, in the solution, which takes place during the prolonged application of compresses so saturated, tends to concentrate the agent in the dressings; hence the well-known effects of the strong solutions, such as blanching, numbing, etc., which lead ultimately to gangrene. So many cases of gangrene from this source have been reported in recent medical literature that topical applications of the drug to the parts mentioned should be practised with extreme caution. *John B. Hamilton.*

Revised by *Louis A. La Garde.*

GARLIC.—Allium. "The bulb of *Allium sativum* L., fam. *Liliaceæ*" (U. S. P.).

Garlic is a compound bulb, globose-ovoid, an inch or two in diameter, of a white or red-brown color and a very strong alliaceous odor and taste. The drug proceeds wholly from cultivated plants.

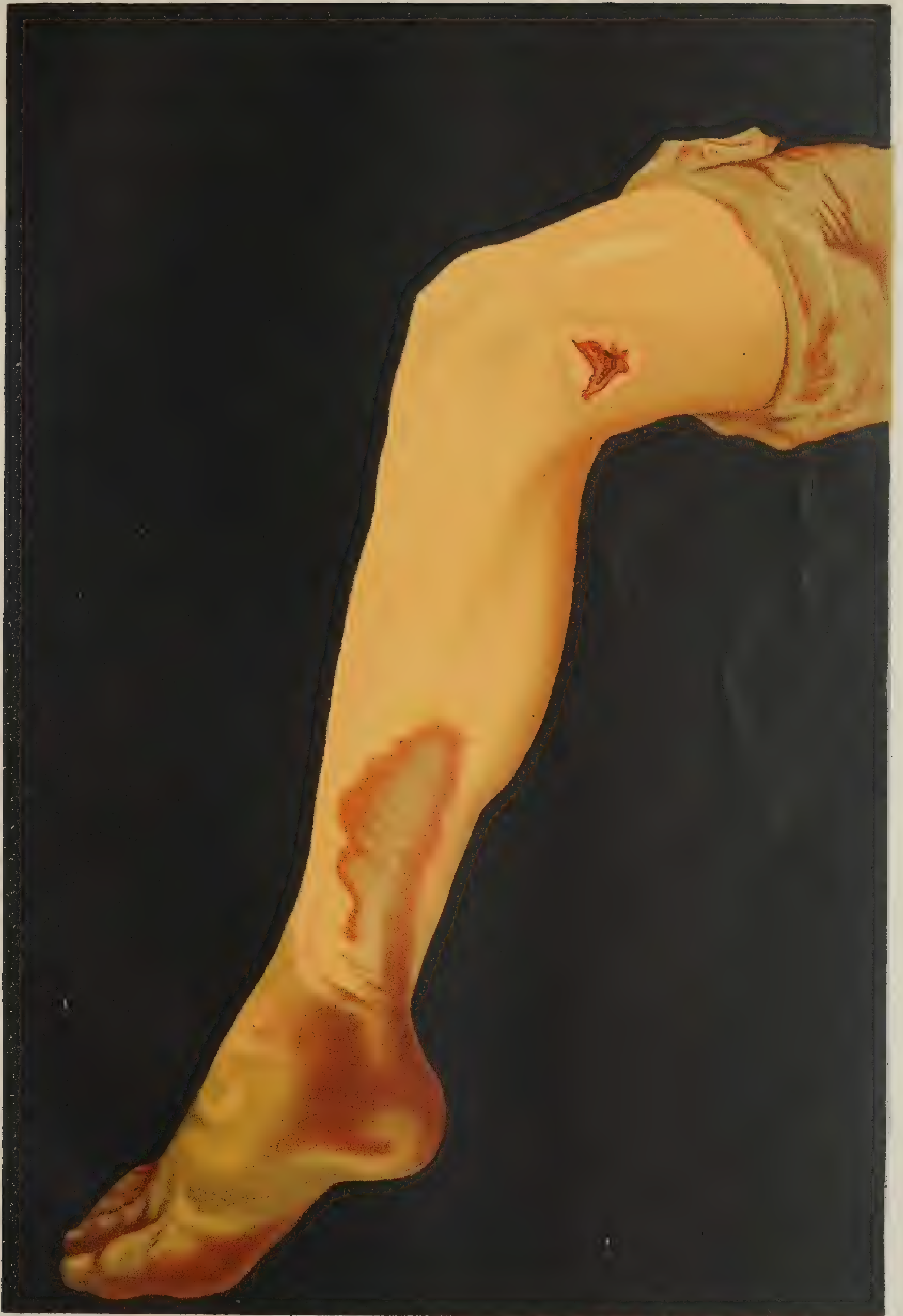
Garlic contains as its active principle—either already formed or produced, as in mustard, etc., by the addition of water—a very irritating, pungent, and volatile oil, *sulphide of allyl,* similar to that of the onion and others of the genus and belonging to the same group with the oils of mustard and other *Cruciferæ.*

It is now and then given with some advantage, as an antispasmodic, and sometimes as an expectorant in chronic bronchitis and pharyngeal or laryngeal catarrh. Internally taken, garlic, like the onion, etc., is an aromatic and carminative, and scents the breath with sulphur compounds during elimination.

There is an official syrup, of twenty-per-cent. strength, which is to be made from the fresh bulbs. Of this the dose is a half-ounce. The fresh juice is also often given in half-drachm doses. The fresh bulb is sometimes crushed and applied to the chest as a rubefacient.

Garlic is likely to be dropped from the next edition of the Pharmacopœia. *Henry H. Rusby.*

GASSERIAN GANGLION, OPERATIVE REMOVAL OF THE.—The Gasserian ganglion is associated with the large sensory root of the fifth cranial nerve. It is situated in a depression near the apex of the petrous portion of the temporal bone. The sensory root of the fifth nerve enters it from behind, while the smaller motor root of the nerve passes under it, without having any connection with it, to join the inferior maxillary nerve.



GANGRENE FOLLOWING A SHOT LACERATION OF THE FEMORAL ARTERY.

(FROM THE MEDICAL AND SURGICAL HISTORY OF THE WAR OF THE REBELLION.)

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Three branches proceed from the anterior border of the ganglion: the ophthalmic, the superior maxillary, and the inferior maxillary. They leave the skull through the sphenoidal fissure, the foramen rotundum, and the foramen ovale respectively. All three branches are nerves of sensation; the inferior maxillary is in addition a nerve of motion since it receives the motor root of the fifth nerve as stated above. It supplies with motor fibres the masseter, deep temporal, buccal, and internal and external pterygoid muscles.

The distribution of the sensory branches of the ganglion is as follows: The ophthalmic branch supplies the eyeball, the lachrymal gland, the conjunctival mucous membrane and that of the nasal fossa, and the integument and muscles of the eyebrow, forehead, and nose. The superior maxillary supplies the integument of the temple and part of the cheek, and the gums and teeth of the upper jaw. The inferior maxillary supplies the integument of the temple, external ear, lower part of the face, and lower lip, the teeth and gums of the lower jaw, and a part of the tongue. It also has a motor function as above mentioned.

The Gasserian ganglion has been of anatomical importance ever since its nature was recognized by Hirsch in 1765. The very great surgical interest which is now felt in this structure, and which is less than ten years old, is due to three facts. The fifth or trigeminal nerve is affected in neuralgia more often than any other nerve. The attacks of pain recur after operations upon the three divisions of the nerve, whether the operation be a simple nerve-stretching, or a division of the nerve, or a resection of a portion of the nerve, or a tearing out of as much of the affected nerve as possible, as advised by Thiersch. The removal of the Gasserian ganglion, first performed by Rose in 1890, affords the patient permanent relief from his neuralgia. It seems like a wanton act to open the skull, burrow in at the base of the brain, and tear out this great ganglion, but desperate conditions demand desperate remedies. Rose removed the superior maxilla and trephined the skull, putting the pin of the trephine in the foramen ovale. His patient recovered with the subsequent loss of an eye, and counted herself happy to be free from the neuralgia even at that price.

Other surgeons soon improved the technique of the operation. Hartley in America, and Krause in Germany, working independently, showed that the skull can be opened, and the ganglion removed by turning downward a flap of skin and bone from the temporal region. In a recent article upon this subject, Krause thus details the steps of the operation as performed by himself:

The patient is in a half-reclining position, with the head held exactly forward or turned a little toward the affected side, so that the blood may flow from the wound. Chloroform is used, if the patient's condition permits. Only dry sponges are employed. A flap of skin, fascia, muscle, periosteum, and bone is cut from the temporal region, and reflected downward. The base of this flap is about 1.5 inches wide and overlies the zygomatic process. Its height is 2.5 inches, and its greatest breadth is 2 inches. The dura mater is not opened. When all bleeding has been stopped by compression and ligature, and the flap, wrapped with gauze, has been reflected downward on the cheek, well out of the way, the dura is separated from the skull down to the bottom of the middle fossa, and the middle meningeal artery is exposed and ligated in two places and then divided. There is usually considerable venous hemorrhage due to the separation of the dura from the base of the skull. This can be controlled by pressure. The next step in the operation is the lifting up of the brain by means of a long retractor, and the dissection of the second and third branches of the fifth nerve from their origin in the Gasserian ganglion to their exit from the skull through the foramen rotundum and the foramen ovale. Then the ganglion itself is freed, at least above and below and backward, until the fifth nerve comes into view. The first division of the fifth nerve, the ophthalmic nerve, is then cut off close to the ganglion, no attempt being made to dissect it free, on account of the danger of injury to the third and fourth cranial nerves, which are intimately associated with it. As these nerves supply the muscles of the eye their injury would be a serious calamity. The fifth nerve is next seized with a pair of clamps close behind the Gasserian ganglion. The second and third divisions are cut off close to their foramina of exit. The ganglion and as much of the root of the fifth nerve as can be twisted out with it, is torn from the brain. The stumps of the second and third divisions are pushed outward through the foramina so as to prevent any union of divided nerve fibres. Inspection of the cavity occupied by the ganglion should prove to the operator that the removal has been a complete one. All bleeding is then to be controlled, and the flap of bone and soft parts replaced. The operation lasts usually from one and one-half to three hours. In a favorable case the patient can get up in one or two weeks and be discharged from the hospital in three weeks.

The two chief dangers of the operation are hemorrhage and prolonged pressure of the brain. The mortality of the operation is variously reckoned at from ten to twenty per cent. The patient awakes from his narcosis absolutely free from neuralgia. This is in striking contrast to the recovery after operations upon the peripheral nerves, since after these operations the attacks of pain recur for a few days in gradually diminishing intensity.

So far as is known removal of the Gasserian ganglion invariably gives permanent relief from the neuralgic attacks, although as the operation has been performed only in the last few years, one must not speak too positively. The numbness and partial paralysis of the muscles of mastication of the side operated upon are a small price to pay for relief from the fearful attacks of pain which these patients have been compelled to endure.

Edward Milton Foote.

GASTEIN.—A picturesque valley in the Duchy of Salzburg, Austria, famous for its mineral springs. It is an arm of the Salzbach Valley, and is about twenty-five miles long by a little more than a mile wide. Its sides are formed by two ranges of mountains which extend to the right and left from the two peaks, Nassfeld-Tauern, 7,820 feet high, and the Ankogel, of 10,700 feet. The situation is romantic, near the region of the glaciers, and at an elevation of about 3,000 feet. In the midst of the valley flows the dashing little river Ache, which forms two beautiful waterfalls near the village of Wildbad-Gastein, now the principal resort. The climate is mild and uniform, the variations in temperature being slight. It is claimed that the thermometer has never risen above 86° F. in summer and seldom above 70°. The barometric changes are also slight, averaging 29.50 inches pressure for the year. Rainy days are, however, rather numerous in the summer.

The thermal springs are eighteen or twenty in number, and are said to have been known as early as the seventh century. Many of them are designated by such names as the Fürstenquelle, the Hauptquelle, the Doctor's-Quelle, and the Spitalquelle. Seven of the springs issue from the solid granite rock or from artificial clefts; the others flow from stratified beds of feldspar, gneiss, and mica. Their deep origin is probably in the heart of the great Ankogel. The temperature of the springs ranges from 87° to 160° F., with but slight variation at any season. The waters are rich in the variety of their mineral salts, but they are very dilute. Of sodium sulphate, the most abundant ingredient, there is but 1.51 grains in a pint, while of calcium carbonate and sodium chloride, the next most abundant ingredients, there is only 0.36 grain each. Oxygen is found in 30.89 per cent. and nitrogen in 69.11 per cent.

The waters are employed almost entirely for bathing, for which purpose many public and private institutions have been erected. Their fame is said to have originated from the cure of Duke Frederick, of Austria, in 1436. Much of the efficacy attributed to them belongs no doubt to the bracing mountain atmosphere.

The baths are recommended chiefly for nervous disorders, especially in cases not amenable to more vigorous treatment. Their beneficial effects in senile marasmus have given them the name of "baths of the aged." Hysteria, hypochondriasis, spinal irritation, impotence, tabes dorsalis, paralysis, neuralgia, rheumatism, disorders of nutrition or of the blood-making functions, as well as pelvic exudations and wasting diseases, are in the category of especial indications. Gastein is also recommended as an after-treatment to a course at Carlsbad, Marienbad, and other springs. *James M. French.*

GASTRECTOMY, ETC. See *Stomach, Surgery of the.*

GASTRIC JUICE.—Nothing was known about the gastric juice until the middle of the last century. By some physiologists gastric digestion was supposed to be merely a mechanical process, the food being triturated by the contraction of the muscular walls of the stomach, as had been observed in the gizzards of fowls. By others the food was supposed to be reduced to a fluid state by maceration under the influence of the warmth of the stomach. By still others the vague and indefinite term fermentation was used to describe the unknown process going on within the stomach. Réaumur (1752) demonstrated satisfactorily by his experiments on a tame buzzard that meat was dissolved in the stomach under the influence of an acid fluid possessing antiseptic qualities. Stevens (1777) came to essentially the same conclusions by experimenting on a human being who possessed the power of regurgitation; and he was the first to carry on digestion outside the body by means of the gastric juice of a dog. Spallanzani (1777–83) deserves credit for having established beyond reasonable doubt that digestion is performed by a fluid in the stomach, and to this fluid, whose acidity and antiseptic properties he likewise recognized, he gave the name gastric juice. At the beginning of the present century this view was accepted and taught by nearly all physiologists.

The next great addition to our knowledge was made by Beaumont (1833), and his contribution may justly be called the most important one ever made to the science of gastric digestion. His observations were made upon a Canadian, Alexis St. Martin, in whom a permanent gastric fistula remained after a gunshot wound. As a result of these observations he described the gastric juice "as a clear, transparent fluid, inodorous, a little saltish, and very perceptibly acid. Its taste when applied to the tongue is similar to thin mucilaginous water slightly acidulated with muriatic acid." He further described it as powerfully antiseptic, and an effectual solvent of food.

In the winter of 1832–33 he submitted a sample of gastric juice contaminated with a little mucus to Professor Dunglison for examination. Dr. Dunglison reported that, in collaboration with Professor Emmet of the Virginia University, he had found the gastric juice to contain "free muriatic and acetic acid, phosphates and muriates, with bases of potassa, soda, magnesia, and lime, and an animal matter soluble in cold water, but insoluble in hot." He expressed astonishment at the large amount of free muriatic acid present.

Prout in 1824 had already declared that the acidity of the gastric juice was due to free hydrochloric acid.

In 1836 Schwann concluded that the digestive power of the gastric juice was due to some unknown active principle which he called pepsin, though he could not isolate it as a distinct chemical substance. This was done by Wassmann (1839) who prepared an impure pepsin as a yellowish powder soluble in water.

Lab ferment was discovered and isolated (also in an impure state) by Hammarsten in 1872.

During the past two decades experiments on animals and direct observations of the gastric juice of man, by means of gastric fistulæ and the stomach tube, have enabled us to gain more accurate information concerning the physical and chemical properties of gastric juice. It is probable that the chemical composition of the gastric juice varies somewhat under different conditions, and that the secretion adapts itself in a measure to the physiological task to be performed. The gastric juice secreted reflexly as a result of the *sight* or *smell* of savory food seems to differ slightly from that secreted after the *ingestion* of food; and it is probable that different foods call forth variations in the chemical composition of the secreted fluid. Beaumont had noticed that the gastric juice was by no means always the same. He noted that exercise leading to perspiration increased the secretion from the gastric cavity; that the fluid poured out under these conditions was only slightly acid, and that it had inferior solvent properties. The ingestion of alcohol in strong solution is known to cause a transudation from the gastric mucosa, the resulting fluid having but little resemblance to gastric juice. Our knowledge, however, of these physiological and pathological variations from the normal is as yet very fragmentary. The quantity of gastric juice secreted in twenty-four hours has never been even approximately determined and estimates range from 180 gm. to 6.5 kgm. The gastric contents as usually removed are made up of food, swallowed saliva, mucus, and gastric juice. As this mixture is being propelled constantly in small quantities into the duodenum throughout the whole process of digestion, any estimate of the total quantity of gastric juice must be subject to very great inaccuracies and no reliable data are at hand.

Human gastric juice contains about five per cent. of solids. Its specific gravity varies from 1.001 to 1.010; the average in the human being is between 1.002 and 1.003.

The mineral salts are chiefly the chlorides of sodium, potassium, and calcium, and the phosphates of magnesium, calcium, and iron. Together they constitute only two per cent. of the gastric juice.

The gastric juice is not rendered turbid by boiling, and is lævo-rotatory. It contains a trace of proteid (probably a peptone) and some mucin. Lactic acid, which until recently was considered a component part of normal gastric juice, is not present in the pure secretion, but occurs as a result of the fermentation of ingested carbohydrates. The active elements of the gastric juice are hydrochloric acid, pepsin, and lab ferment.

Neither the pepsin nor the lab ferment has ever been isolated in a chemically pure state.

Hammarsten separated lab ferment (rennin) from pepsin by fractional precipitation with lead acetate. Gamgee has summarized the qualities of an approximately pure solution of rennin as follows: It is not coagulated by heat; it is not precipitated by alcohol, nitric acid, tannin, iodine, nor by sugar of lead, but by basic lead acetate.

Lab ferment is not diffusible. It is destroyed by 0.5 to 1 per cent. Na_2CO_3.

Its chief characteristic is its power to clot solutions of casein. This it accomplishes by splitting up the casein into two forms of proteid, one of which remains in solution, while the other coagulates in the presence of lime salts.

Pepsin is probably not a proteid. It is soluble in water and glycerin. It is non-diffusible. In the presence of free mineral acid (especially hydrochloric) it has the property of changing albumin into peptone. It is rendered inert by alkalies.

The hydrochloric acid in the gastric juice exists partly in the free state and partly combined with some of the organic and inorganic constituents of the juice. In man the free acid constitutes from 1 to 2 pro mille of the pure gastric juice. In dogs the acidity is higher; in herbivorous animals it is less. When food is ingested the gastric mucous membrane secretes hydrochloric acid until the chemical affinity of the food for hydrochloric is satisfied, and then it continues to secrete acid until the amount of free acid present has reached a certain norm for that individual, usually 0.12 to 0.18 per cent. After the norm has been reached the secretion of acid comes to a standstill, and by this reflex mechanism the overproduction of hydrochloric acid is prevented in the healthy stomach. *Henry Wald Bettmann.*

GASTRULA.—(Dim. of L. *gaster* from the Greek γαστήρ, belly, stomach.) The *gastrula* is a stage in the embryonic development of at least one representative of nearly every great group of animals above the Protozoa. Moreover, those forms which do not possess a typical gastrula stage are found on careful examination to exhibit, with few exceptions, structures or modes of development which may be interpreted as vestiges of this stage.

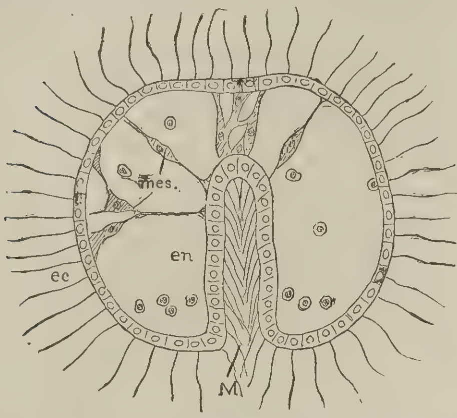

FIG. 2268.—Section of a Gastrula of a Sea-Urchin, *Toxopneustes lividus.* (After Selenka.) Highly magnified. *ec*, Ectoderm; *en*, endoderm; *mes*, mesoderm; *M*, blastopore.

In holoblastic eggs with equal cleavage (see article *Segmentation of the Ovum*) the cleavage results in the formation of a typical *blastula*. This is a rounded body composed of cells, the *blastomeres*, forming a continuous membrane, the *blastoderm*, which encloses a cavity, the *blastocœl*.

The next stage is the *gastrula*, which is formed from the blastula usually by the invagination of its wall on one side. By this process the blastoderm becomes differentiated into the two primary germ layers. The part which remains on the outside is the *ectoderm*, and the part which is invaginated is the *endoderm*. (See *Germ Layers*.) In most animals the cells of the blastula are not all alike, those on one side, the animal pole, being smaller and containing less deutoplasm (yolk granules) than those on the other side, the vegetative pole, which are in many cases very large and heavily laden with deutoplasm. When such differentiation obtains it is always the cells of the vegetative pole that are invaginated to form the endoderm.

The nearly typical gastrula of a sea-urchin is represented in longitudinal section in Fig. 2268. This embryo contains two cavities,—one a closed cavity, the blastocœl, lying between the ectoderm (*ec*) and the endoderm (*en*), and the other, the primitive stomach, or *archenteron*, a cavity entirely surrounded by endoderm, except at one side, where it opens to the exterior by the primitive mouth, or *blastopore* (*M*). At the lips of the blastopore the ectoderm and endoderm are continuous. This embryo is not quite a typical gastrula on account of the presence in the blastocœl of mesenchyme cells (*mes*), which in most animals appear at a somewhat later stage.

Gastrulas of this same general type are to be met with in the sponges, cœlenterates, echinoderms, nemertians, annelids (Eupomatus), sipunculids, chætognaths, crustacea (Lucifer), mollusks, and chordata (tunicates and Amphioxus).

Of these various forms, the one of most interest to us is the gastrula of Amphioxus. If one were to draw a diagram to show the essential structures of a vertebrate reduced to their simplest forms, the drawing with slight alterations could be made to represent an amphioxus. This is a little fish-like animal an inch or two in length, that lives in the sand in shallow arms of the sea in various parts of the world. It is found in the Chesapeake Bay, in the lagoons of the Bahamas, and the writer has gathered hundreds of specimens on the sand flats by the railroad wharf at Port Tampa, Florida. The Amphioxus, having little more than a notochord by way of skeleton, has left no fossil remains, but its habitat is exactly similar to that in which countless generations of Lingula have dwelt with practically no change of structure, so far as we can see, since lower Silurian times. So it is not impossible that we may be right if we infer from its structure that Amphioxus is also of a very ancient type, and is a living representative of our ancestors, that lived before the appearance of the earliest fishes. For this reason the embryology of this form is of special interest. This proves to be just as diagrammatically primitive as the structure and confirms our inference from comparative anatomy.

The gastrula of Amphioxus (Fig. 2269) is a typical one of the *embolic* type. That is, the archenteron is formed, as in the sea-urchin, by the invagination of the endoderm. This is contrasted with the *epibolic* type of gastrula in which, owing to the large size of the slowly dividing endodermal cells, heavily laden with yolk, an invagination is impossible, and the smaller and more active ectodermal cells form the gastrula by growing over and around the large and less active endodermal cells. These types of gastrula grade into one another, so that in some cases it is difficult to tell to which type the gastrula belongs.

Fig. 2269 represents a vertical longitudinal section of a gastrula of Amphioxus. The archenteron is large and the endoderm is so closely pressed against the ectoderm that the blastocœl is obliterated except in a small space near each lip of the blastopore, which at this stage is widely open. The development of the gastrula of this species is represented in Fig. 2270.

The eggs of Amphioxus are laid, according to Wilson, as a rule, between five and six in the afternoon. Cleavage results in the formation of a globular blastula; and about midnight, according to Morgan, gastrulation begins by the flattening of one side of the blastula. This side may be distinguished from the other by the presence of larger cells more completely filled with yolk granules. About two hours later the flattened side has pushed inward until the endoderm nearly touches the ectoderm and the embryo has become saucer-shaped (Fig. 2270, *a*).

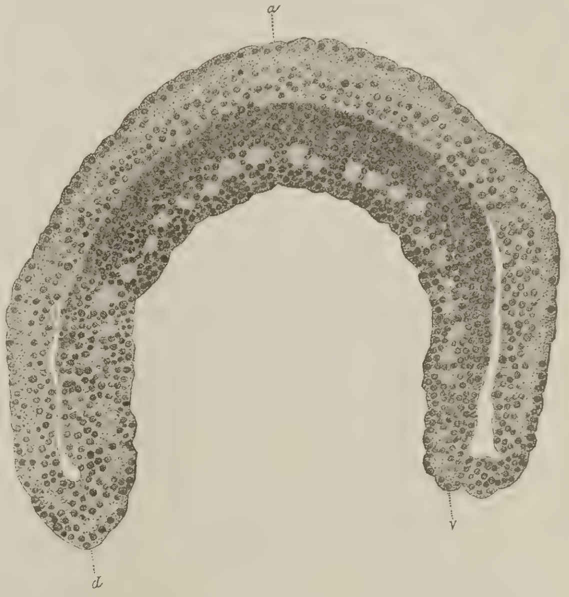

FIG. 2269.—Sagittal Section of a Gastrula of Amphioxus at 4 A.M. *a*, Anterior pole; *d*, dorsal lip of the blastopore; *v*, ventral lip. Reduced from camera drawing made with Zeiss 4, oil immersion 2 mm. (After Morgan and Hazen.)

From this time on there is a gradual closing of the blastopore accompanied by the growth of its lips, until, when the blastopore is nearly closed, the embryo has the shape of a football (Fig. 2270, *d*), the small opening being a slight distance from the posterior end of the long axis of the embryo and on the dorsal side of it. The end of the gastrula stage is marked by the closure of the blastopore from direct communication with the exterior. But for a long time the inner part of it forms a passageway from the archenteron into the developing neural tube, it is then called the *neurenteric* canal.

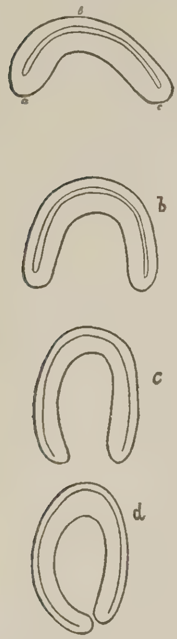

FIG. 2270.—Four Stages in the Development of the Gastrula and Closure of Blastopore of Amphioxus. Sagittal sections. *a*, Ventral lip of blastopore; *b*, anterior pole; *c*, dorsal lip. (After Morgan and Hazen.)

The simplest form of gastrula to be found in the true vertebrates is of the type observed in the cyclostomes, ganoids (Fig. 2271), and amphibians (Figs. 2272 and 2273). In the eggs of these forms the cleavage is always unequal and may be holoblastic as in the frog or meroblastic as in the gar-pike. In either case it results in the formation of a blastula in which the blastocœl is excentric, lying near the upper pole. In either case the roof of the blastocœl is composed of one or more layers of small cells, while its floor is composed of large cells or imperfectly divided yolk. The formation of the gastrula begins by the development of a slight groove on one side near the edge of the area of small cells. The upper edge of this groove is the dorsal lip of the blastopore. The ends of the groove extend in a circle until they meet, completing the blastopore at its ventral lip. Within the blastopore there is a mass of large endodermal cells, the so-called *yolk-plug*. The formation of the blastopore has been observed in living eggs of a number of amphibians by several investigators. The observations of H. V. Wilson upon a tree frog (*Chorophilus feriarum*) are of special interest because by the skilful use of an inverted microscope he was able to watch the changes in uninjured eggs in their normal position. He finds that all parts of the edge of the blastopore, as soon as they are formed, begin to grow over the yolk cells. During this process, not only the yolk cells disappear under the advancing edge of the blastopore, but cells outside of the blastopore are seen to move to the edge and then to roll over and disappear beneath it, so that there is here a combination of overgrowth (*epiboly*) and invagination (*emboly*). The dorsal lip being the first to form, Wilson finds that it grows over an angular distance of 25° before the ventral lip starts, at which time the width of the blastopore is 95°. After that the rate of closure is equal on all sides.

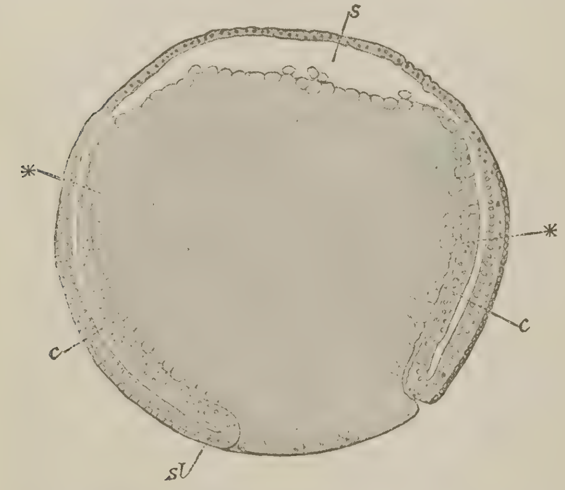

FIG. 2271.—Sagittal Section of a Gastrula of Forty Hours of the Gar-pike, Lepidosteus. *c*, Endoderm; *sl*, dorsal lip of blastopore; *s*, blastocœl; * *, innermost limit of archenteron. (After Dean.) × 30.

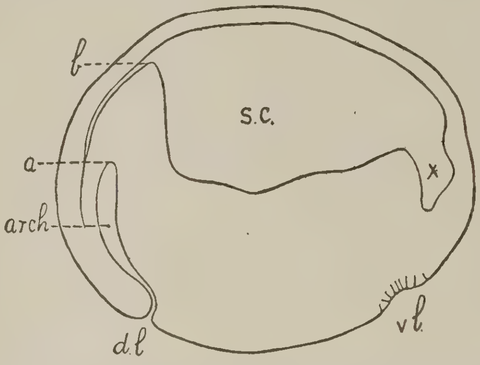

FIG. 2272.—Sagittal Section of the Gastrula of a Tree-toad, Chorophilus. *arch*, Archenteron; *a–b*, "tongue" of uncleft yolk in front of archenteron; *d.l.*, dorsal lip; *v.l*, ventral lip, *s.c.*, blastocœl; *x*, space produced artificially. (After H. V. Wilson.) Camera drawing, Zeiss A, 2.

When the blastopore has been reduced to a very small opening, the overgrowth stops at the dorsal and ventral sides, but continues laterally, so that the blastopore finally becomes a mere slit and at length the lips fuse in the middle, leaving a minute opening at each end. The dorsal one is the neuropore, or neurenteric canal, and the ventral one may or may not persist as the permanent anus.

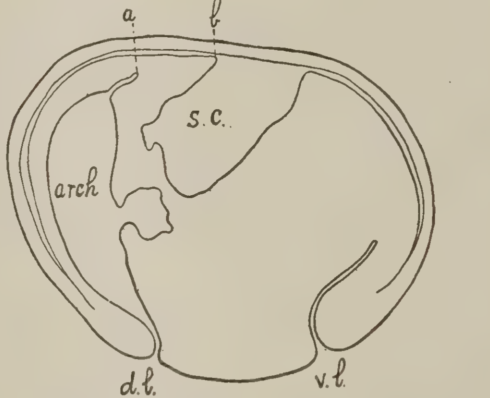

FIG. 2273.—Sagittal Section of the Gastrula of a Tree-toad, Chorophilus. Later stage than that shown in Fig. 2272. Reference letters the same. (After H. V. Wilson). Zeiss A, 2.

Figs. 2271, 2272, and 2273 represent sagittal sections of gastrulas of the gar-pike and the tree frog. Comparing these with Fig. 2269 we see that they are similar to the gastrula of Amphioxus, except that in these forms the endoderm forming the ventral and anterior wall of the archenteron is greatly thickened so as nearly to fill the cavity of the archenteron and to protrude through the blastopore.

In the Sauropsida, reptiles and birds, we find an enormous increase in the proportion of yolk in the egg.

Nevertheless, there is a stage in the development of these forms that may be regarded as a gastrula. The hen's egg may be taken as the type of this class. Cleavage begins and the egg passes through the blastula stage while in the oviduct. The germinal area in the blastula stage consists of two layers of cells. The outer layer forms a membrane of completely divided cells and is separated by a shallow cavity, the blastocœl, from the lower layer of cells, in which the cell boundaries are incomplete, so that the cells are not separated from the white yolk below. At the margin of the germinal area the two layers are united and all the cell boundaries are incomplete below.

At about the time that the egg is laid the posterior border of the germinal disc becomes sharply defined by the appearance of a crescentic groove, which gradually extends around toward the anterior side. Inside of the groove the disc becomes thicker and more opaque. The gastrula stage begins with the formation of this groove and ends with the completion of the primitive streak.

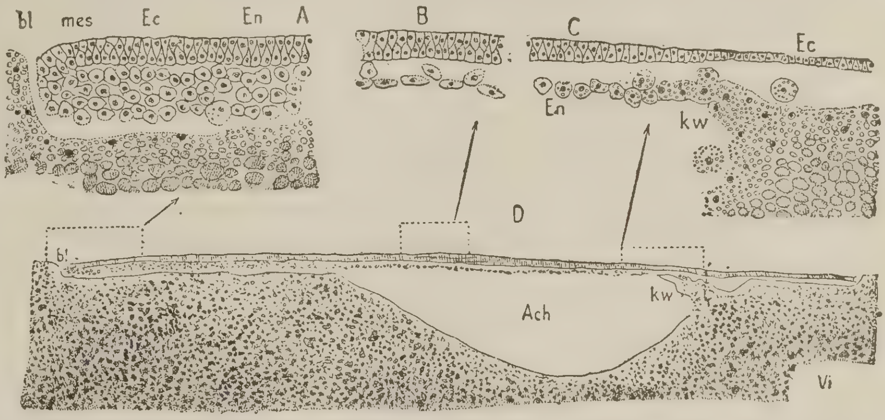

Fig. 2274.—Sagittal Section through the Blastoderm of a Hen's Egg Incubated Six Hours. *Ach*, Archenteron; *bl*, dorsal lip of blastopore; *Ec*, ectoderm; *En*, endoderm; *kw*, germinal wall; *mes*, marginal rim; *Vi*, Yolk. (After Duval, from Minot.) *D*, × about 40; *A*, *B*, *C*, details of *D* more highly magnified.

The blastocœl quickly disappears and the groove opens into a new cavity lying between the germinal disc and the yolk, the subgerminal cavity or archenteron. Fig. 2274 represents a sagittal section through a late gastrula stage of the hen's egg and may be compared with the dorsal half of the gastrula of the frog, Fig. 2273. At the anterior end of the section the ectoderm is seen to be growing over the yolk while the endoderm below is continuous with the yolk (*kw*), while at the posterior end the endoderm and ectoderm are continuous with one another and separated from the yolk by a slit (*bl*), which connects with the archenteron and may be regarded as homologous with the blastopore of the frog. As in the frog the blastopore begins as a crescentic groove and the dorsal lip proceeds to grow backward over the yolk. But, unlike the frog's egg, the egg of the hen contains so much yolk that the ends of the crescent are unable to meet around the yolk-plug. So the closure of the blastopore is effected in another way,—by the progressive separation of the ectoderm from the endoderm, beginning at the ends of the crescent, and the growth of the ectoderm as a distinct layer over the yolk, as described in the article on the *Area embryonalis* (see Vol. i., pp. 441, 442).

In the mammalia, although the egg is minute and undergoes a holoblastic cleavage, the development of the embryo is a very complex process, to be explained probably by the supposition that the ancestors of the mammals had eggs with a large amount of yolk. In this group the gastrula stage has almost entirely disappeared, the stage figured by Haeckel as such not being a gastrula at all. Hubrecht, however, described structures in the primitive streak of the shrew (Sorex) that resemble what is found at the lip of the blastopore of the frog, and he finds there a minute canal that he regards as a vestige of the neurenteric canal.

The gastrula has been a stage of more than ordinary interest to embryologists because of the importance attributed to it in the *Gastræa Theory* of Haeckel. This theory is based primarily upon the discovery made by Huxley in 1849: "That a Medusa consists essentially of two membranes enclosing a variously-shaped cavity, inasmuch as its various organs are so composed"; and that "a complete identity of structure connects the foundation membranes of the Medusa with corresponding organs in the rest of the series; and it is curious to remark, that throughout the outer and inner membranes appear to bear the same physiological relation to one another as do the serous and mucous layers of the germ; the outer becoming developed into the muscular system and giving rise to the organs of offence and defence; the inner, on the other hand, appearing to be more closely subservient to the purposes of nutrition and generation." To these two layers Allman in 1853 gave the names ectoderm and endoderm, respectively. Later, Alexander Kowalevsky, beginning in 1866, made a brilliant series of observations upon the embryonic development of a large number of invertebrates, corals, hydromedusæ, scyphomedusæ, ctenophores, worms, Phoronis, brachiopods, echinoderms, mollusks, and insects, and also upon various lower chordata, including tunicates, Amphioxus, and fishes. He concluded that in all the invertebrates that he had studied, two germ layers are formed at the beginning of development, and that in most cases there is formed at first a vesicle of cells, one side of which becomes invaginated, forming a double cup with a central cavity opening to the exterior. He found a similar condition in tunicates and Amphioxus and by comparison of their subsequent stages of development demonstrated the affinity of the tunicates with Amphioxus and, through that form, with the true vertebrates.

In 1872 Haeckel published a description of the two-layered, cup-shaped larva of the calcareous sponges, and asserted that this stage, to which he gave the name *Gastrula*, is a fundamental one for all metazoa.

In 1874 and 1875 he elaborated more fully the theory that the gastrula represents the type of the most primitive metazoan, the common ancestor of the whole great group of animals above the protozoa. To this hypothetical ancestor he gave the name *Gastræa*. As already indicated, this generalization of Haeckel has been, in the main, confirmed by subsequent investigations.

Robert Payne Bigelow.

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GAYLORD AND GULICK MINERAL SPRINGS.—(Formerly Blossburg Mineral Springs.) Tioga County, Pennsylvania.

POST-OFFICE.—Blossburg. Hotels in the village.

ACCESS.—Viâ Tioga branch of Erie Railroad to Blossburg; also viâ Northern Central Railroad to Roaring Branch, and thence by stage line over the mountains.

These springs are located in a picturesque mountain region 1,500 feet above the sea-level. They are surrounded by a charming tract of woodland containing 213 acres, from which a fine view of the valley of the Tioga may be obtained. The place offers many attractions as a summer resort, but is not fully developed as yet. The springs are two in number, and flow about 1,800 gallons of water per hour. The following analysis was made by Prof. F. A. Genth in 1879:

SULPHATED ACID CHALYBEATE.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Magnesium sulphate	13.10
Calcium sulphate	23.13
Lithium sulphate	.12
Sodium sulphate	.27
Potassium sulphate	.24
Sodium chloride	.10
Manganese sulphate	1.83
Cobalt sulphate	.03
Nickel sulphate	.36
Aluminum sulphate	6.58
Iron sulphate	31.31
Iron phosphate	.32
Sulphuric acid	5.64
Silicic acid	2.15
Total	85.18

This analysis shows a sulphated acid chalybeate water of great potency. It is remarkably rich in ferruginous ingredients, and contains a considerable proportion of the sulphate of magnesia or Epsom salt. The analysis also shows appreciable quantities of the rare ingredients manganese, nickel, and cobalt. The water possesses excellent properties as a tonic and reconstructive, and has been found very useful in conditions characterized by anæmia and general debility. It is also used in dyspepsia and intestinal disorders. Locally it has decided astringent and stimulant effects, and as such is recommended as a douche, spray, gargle, or lotion. The water is used commercially. A mineral water of this strength should always be taken under the direction of a physician. *James K. Crook.*

GEISSOSPERMUM.—*Pao Pereira Bark.* The bark of one or more species of *Geissospermum* (fam. *Apocynaceæ*), *G. læve* Miers being the important one, used in Brazil as a febrifuge. Three alkaloids have been reported, *geissospermine, pereirine* (this is not the only alkaloid of this name), and *vellosine* (from *G. Vellosii* Allem.). The drug and its alkaloids have been used experimentally, especially in Europe, but have found no accepted position in medicine. *Henry H. Rusby.*

GELATIN.—GELATINUM. *Gelatin* has been defined by the British Pharmacopœia as "the air-dried product of the action of boiling water upon such animal tissues as skin, tendons, ligaments, and bones." It appears in a variety of forms. That which has not been purified, made usually from animal matter which has partly decomposed, is *glue.* When purified by special processes it becomes *sparkling.* It usually occurs in sheets which have been dried upon coarse matting, but frequently in narrow strips cut from such sheets (*shredded gelatin*). Gelatin should be almost or quite colorless and transparent, without odor, and nearly tasteless. Dissolved in 50 parts of hot water, it should yield a firm jelly on cooling. The aqueous solution is precipitated by tannin, but not by alum, subacetate of lead, or ferric chloride T. S. Gelatin is soluble in acetic acid, but not in strong alcohol or ether. It has no medicinal activity, but is a nutrient of the albuminoid class, used in the diet of invalids and in the kitchen generally. Its chief use in medicine is, strictly speaking, pharmaceutical, for the manufacture of the well-known soft and hard gelatin capsules and for the coating of pills.

Gelatose is gelatin which, as a result of certain changes, especially those of bacterial causation, can no longer be gelatinized. *Henry H. Rusby.*

GELSEMIUM.—YELLOW JASMINE, YELLOW JESSAMINE. "The dried rhizome and roots of *Gelsemium sempervirens* (L.) Ait. f. (fam. *Loganiaceæ*)," U. S. P. The yellow jessamine of the Southern States is a pretty climbing shrub, with a large woody rhizome, and numerous fine roots, and slender, smooth, twining, purplish stems. It has dark green, glossy, lanceolate, entire, evergreen leaves, growing opposite to each other, and bearing in their axils solitary or clustered flowers. The latter are large, sweet-scented, bright yellow, and slightly irregular. Calyx small, of five-pointed sepals; corolla funnel-shaped, with a slightly oblique, five-lobed border; stamens five, perigynous. Fruit an oblong, flattened, drooping pod; seeds margined. This is one of the most attractive flowers in the Southern States. It grows abundantly from Virginia southward, in woods, and mounts to the tops of tall trees. The flowers, which appear in the spring, load the air with their sweet odor.

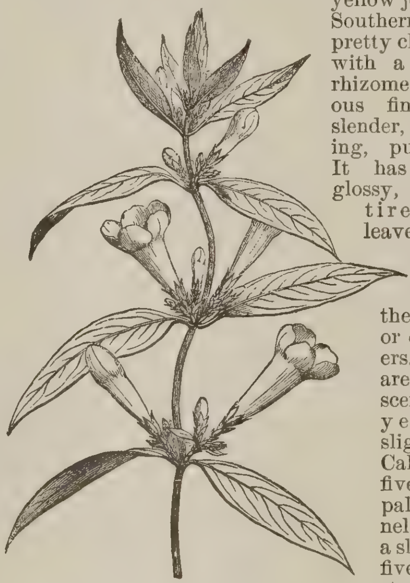

FIG. 2275.—Yellow Jasmine.

Of course, so conspicuous a plant was early noticed; in fact, it was carried to England as an ornament in the first half of the seventeenth century. Its poisonous properties were also early known, but its medicinal employment is of rather recent date.

DESCRIPTION.—Rhizome cylindrical, short-flexuous, elongated or cut in sections of variable length, mostly from 0.5 to 1.5 cm. ($\frac{1}{5}$ to $\frac{3}{5}$ in.) and occasionally 3 cm. (a little more than an inch) in diameter, the roots much thinner, a few elongated, unbranched, coarsely hair-like tough rootlets usually attached; externally of a light yellowish-brown, commonly with some purple or purplish-brown longitudinal lines or patches, or occasionally deep purple-brown with yellowish-brown, fine ridges; heavy, hard, and tough; internally yellowish-white; fracture of the rhizome splintery, the roots breaking with half the fracture transverse, the other oblique or short-splintery; bark thin, closely adhering, that of the rhizome with fine, silky bast fibres, the wood porous, with numerous fine medullary rays; odor peculiar; taste slightly aromatic, bitter.

COMPOSITION.—It contains two alkaloids, *Gelsemine* ($C_{49}H_{63}N_5O_{17}$), crystalline, but inert upon the human subject, and *Gelseminine* ($C_{12}H_{14}NO_2$), which, like its salts, is amorphous, occurring as a white powder, soluble in alcohol, not in water, and which is the active constituent. Gelseminic acid is a saponin-like substance. A little resin and volatile oil, with starch, are also present.

ACTION AND USE.—Gelsemium is an active paralyzing poison, capable of killing both animals and man in small doses, expending its action upon the nervous system. It does not affect consciousness until near the end of fatal cases; sometimes, but not always, it produces convulsions, due apparently to respiratory interference. Reflex excitability is increased at first, afterward diminished, while its paralyzing effect upon the motor columns steadily increases to the end. Death takes place by asphyxia, proceeding from central paralysis. It depresses or paralyzes the nerve endings to a less extent, and less promptly than the centres. Locally, and to a less extent systematically, it dilates the pupil and paralyzes the power of accommodation precisely like atropine. The following symptoms are observed in man after moderate doses: languor, debility, dizziness, disturbances of vision, dilatation of the pupils, paresis, especially of the flexors of the arm, and drowsiness. The poison appears to be quickly absorbed and promptly eliminated. This root, whose medicinal value is said to have been discovered by accident, has been considerably used in the South and West in the treatment of malarial and other fevers. It is occasionally employed in pneumonia and pleurisy as a depressant; in asthma, whooping-cough, etc., it is also indicated, but is not, in the East at least, very frequently given. In neuralgias it holds, perhaps, its place most firmly. It has also been useful when dilatation of the pupil is desirable, differing from atropine in the transientness of its effects.

ADMINISTRATION.—From 25 to 30 cgm. (0.25 to 0.30 gm. = gr. iv. ad gr. v.) of the powder, or the same measures of the fluid extract (*Extractum Gelsemii Fluidum*, U. S. P.) are suitable doses. The official 15-per-cent. tincture is given in doses of 1–4 c.c. (fl. ʒ ¼–i.).

It has been observed quickly to counteract mild disturbances due to overdoses of strychnine, and might be found efficacious as an antidote to that poison.

W. P. Bolles.

GELSEMIUM, POISONING BY.—In Gelsemium sempervirens are found an acid and two alkaloids. The alkaloids are gelsemine and gelseminine. Gelsemine has a tetanizing action, and causes in the frog violent spinal excitement with increased reflexes followed by paralysis due to the action upon the nerve endings. Gelseminine is the more active of the two, producing a paralysis by direct action upon the spinal centres, and having a curare-like paralytic influence upon the nerve trunks. The acid, gelseminic acid, was by Robbins regarded as identical with æsculin, the glucoside of the horse chestnut; Dragendorf and Schwartz arrived at similar results, but Professor Wormley in re-investigating the subject proved that gelseminic acid is not identical with aesculin. According to Kunkel, the acid is of no toxicological importance. Nottage says that commercially the alkaloids are found as a crystalline alkaloid and an amorphous alkaloid of which the former has about ten times the potency of the latter. From the amorphous alkaloid the dosimetric granules are commonly made. The paralyzing alkaloid is the more potent and causes the characteristic symptoms in poisoning from preparations of the whole plant, such as the tincture or fluid extract. The symptoms come on usually within a half-hour, but in some cases the action is immediate. A full dose gives rise to languor, muscular relaxation, and weakness, drooping of the eyelids, double vision, and dilated pupils. When a poisonous dose is taken the muscular relaxation is more pronounced, the jaw usually drops, the skin becomes cold and cyanotic, the respiration shallow and weak, the heart is weakened, and at times the patient has such paroxysms of dyspnœa as to clutch at the throat for air. Sensation is not so early impaired as motion, and intellection is preserved in most instances until the impaired respiration poisons the brain.

The fatal dose is difficult to determine. Twelve minims of the fluid extract have proved fatal to a boy of three years; thirty-five drops of the tincture of the bark have resulted fatally in an hour and a half. In one instance known to the writer a drachm of the tincture taken by mistake proved fatal to a young lady in one-half hour. Dr. Hartwell has known twelve grains of the resenoid to result fatally. Recoveries have occurred after the ingestion of considerable-sized doses. Dr. Main recovered in somewhat over an hour after taking by mistake a drachm of the fluid extract. Blake's patient recovered after taking two drachms of the tincture, although the depression was most profound, and there was intense cyanosis with fearful paroxysms of dyspnœa. In my own case of fatal poisoning the patient, who had taken small doses of the tincture at intervals after a debauch without any marked effect, took probably a half ounce of the fluid extract, and when found a half-hour later was intensely cyanosed, pupils dilated, jaw dropped, lids drooped, muscles completely relaxed, with weak heart and shallow and weak respiration. The patient was somnolent, but could be aroused. Despite all efforts death resulted in seven and one-half hours. The poison seems to be a spinal depressant, as is shown by its late involvement of the higher intellectual centres, and the fact that the poison acts upon the pithed frog and when the main artery of an extremity is tied. It seems to be particularly a respiratory poison. After death no distinctive pathological changes are found. There are no true chemical or physiological antidotes. Morphine, which has been extolled as an antidote and which appeared in Blake's and Courtwright's cases to have rendered excellent service, has been shown by Rehfuss in his experiments to be in no sense an antidote, only slightly retarding the effects of gelsemium and not acting in this way as efficiently as atropine.

The treatment of gelsemium poisoning must be conducted upon general principles. The stomach should be evacuated, and the respiration maintained by strychnine, atropine, artificial respiration, and faradism of the respiratory muscles. The heart suffers secondarily, and nitroglycerin and digitalis will be of service in maintaining its action. Rehfuss, as a result of his experimental studies, recommends emetics, ammonium carbonate, brandy, and the early and repeated use of small doses of atropine to sustain respiration; in addition sinapisms, faradic current, and artificial respiration. Jepson used hypodermics of strychnine successfully in one case. In my own fatal case there was very marked improvement following the administration of atropine and nitroglycerin combined with artificial respiration and faradism of the respiratory muscles. The pulse, which had been very feeble, increased in strength, the cyanosis disappeared; the respirations, which had been shallow, feeble, and irregular, became full and deep, so that the lips previously blue became rosy. The patient was lying upon a blanket before an open fire in a rapidly chilling room. The improvement was so marked that we felt the worst had been averted, and we then attempted to move him nearer the fire by lifting him by the corners of the blanket. By this his diaphragm was cramped, and he died instantly —a warning regarding the care which should be used in moving patients under these circumstances. Were the writer to be again confronted with a case of gelsemium poisoning he would rely upon repeated hypodermics of atropine and strychnine, and would, if the Fells apparatus, which has proved so successful in opium poisoning, were at hand, maintain artificial respiration by the aid of this instrument. Faradism of the respiratory muscles is a powerful adjuvant, but that its application to the hands should have had the result of banishing all symptoms "instantaneously and permanently" in Dr. Main's own case seems remarkable.

William Wotkyns Seymour.

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GENEVA LITHIA SPRINGS.—Ontario County, New York.

Post-Office.—Geneva.

Location.—Geneva.

The well-known Geneva lithia water is obtained from an artesian well over eight hundred feet deep, which was bored in 1886. Issuing from a stratum of pervious rock defined by a layer of mediæval sandstone sixty feet thick and a deep substratum of hard slate, the water is forced up by an internal pressure of one hundred and twenty pounds to the square inch, and, if unimpeded at the surface, would form a fountain eighty feet high. The water is bright, clear, and sparkling, being agreeable to the palate and excellently adapted for table use. The following analysis was made by Prof. A. Auchie Cunningham, F.C.S.:

One United States Gallon Contains:

Solids.	Grains.
Magnesium sulphate	83.13
Magnesium carbonate	16.00
Potassium chloride	13.40
Sodium chloride	24.54
Sodium sulphate	17.64
Aluminum sulphate	8.75
Lithium bicarbonate	10.03
Lithium sulphate	4.10
Iron carbonate	2.15
Calcium sulphate	18.75
Calcium carbonate	35.84
Phosphoric acid	Trace.
Total	234.33

There is an entire absence of organic matter. The analysis shows a valuable lithia water, which possesses many excellent qualities. It may be classed as belonging to the lithiated-saline chalybeate variety. Aside from its strong impregnation with the bicarbonate and sulphate of lithia, it possesses enough of the sulphates of magnesium and sodium to give it laxative properties, and enough iron to make it a valuable ferruginous tonic when taken continuously. The water is used commercially, and has an extensive sale. It has the indorsement of many prominent physicians of the great Eastern cities. The water resembles that of a spring at Rippoldsau, in the Duchy of Baden, but is more heavily charged with iron and free phosphoric acid. It is extensively employed in anæmic states and general debility, and in many of the conditions resulting from the uric-acid diathesis, viz., gout, dyspepsia, rheumatism, renal and vesical calculus, Bright's disease, etc. *James K. Crook.*

GENITAL ORGANS, FEMALE. See *Sexual Organs, Female.*

GENITAL ORGANS, MALE.—Embryology of the Genital Organs.—In order to have a proper knowledge of the normal and at times abnormal anatomy of the human male genital organs, it is essential that a brief review of the main facts of their embryology should be presented.

That the higher types of vertebrates, during their development, pass through stages the essentials of which are permanent in some of the forms below them, is particularly well exemplified by a study of the embryology of the genital organs.

In the light of the theory of development many cases of anomaly of the genital organs will furnish striking evidence of either *atavism* or *arrested development.* In the growth of the embryo there is at first a period during which there is no indication of any provision either for a urinary or a generative function. A little later the rudiments of a urogenital apparatus are developed, but as yet there is no evidence of sexual differentiation.

In the course of embryological changes it will be observed that certain of the structures concerned appear and assume their permanent characters. Gradually and without modification of plan other structures, at first employed for purposes unrelated to the urogenital apparatus, become adapted, secondarily, for special purposes in this system; others, though belonging to this system from the first and attaining to a condition of functional activity in one direction, are later adapted to altogether different activities in another direction; lastly, other rudiments, according to the sex developed, either become elaborated into efficient and important parts of the reproductive organs, or dwindle into useless vestiges that never take any part in the normal work of the body.

In order that the reader may appreciate, to some extent, the significance of references to the lower animals, it may be well to state here that Tunicates are the lowest vertebrates known. Then, according to the grade of organization and from the simpler to the higher, come, in order, the Acrania (Amphioxus), Cyclostomes, Fishes, Amphibians, Reptiles and Birds, and, highest of all, the Mammals. The Mammals are further subdivided, according to grade of organization, into the Monotremes, Marsupials, and Placentals.

The common embryonic foundations of the sexual organs, male and female, are as follows, viz.: for the internal organs of generation they are the *germinal gland, the Wolffian duct,* the *mesonephros,* the *Müllerian duct,* a part of the *intra-embryonic allantois,* a part of the *cloaca,* and a part of the *proctodeum* (Figs. 2277 and 2278).

For the external organs of generation they are the *genital eminence, genital groove, genital folds,* and *genital ridges* (Figs. 2281 and 2282).

In intimate relation with the Wolffian duct arise, in orderly sequence, three important structures—viz., the *pronephros* or head kidney, *mesonephros* or Wolffian body (midkidney), and the *metanephros* or hind (permanent) kidney (Fig. 2277).

These nephric structures all lie in the dorsal wall of the embryo's abdominal cavity (cœlom) near the point where the somatic and splanchnic layers join (Fig. 2276); they extend, on either side of the notochord (primitive vertebral column), from the neighborhood of the heart to the tail end of the embryo, one behind the other in the order indicated by their names.

The intestinal, urinary, and reproductive organs are not only intimately related in the adult, but they are still more intimately related in the embryo (Fig. 2277), and therefore they must be referred to, in varying degrees, in describing the development of the male sexual apparatus.

At an early stage of the embryo an evagination occurs from the ventral surface of the hind gut near its caudal end to form the *allantois* (Fig. 2277, *A*). The part of the hind gut caudad of the allantois is the *cloaca* (*Cl*). The cloaca is present permanently in all vertebrates from Fishes to Monotremes.

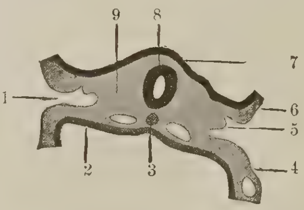

Fig. 2276.—Transverse Section of a Seventeen-Day Sheep Embryo. Diagrammatic. 1, Cœlom (pleuroperitoneal cavity); 2, entoderm; 3, notochord; 4, splanchnic mesoderm or mesoblast; 5, middle plate; 6, somatic mesoderm or mesoblast; 7, ectoderm; 8, neural canal; 9, paraxial mesoblast.

Development of the Internal Genital Organs.—The pronephros and Wolffian duct are evolved as follows: the mesothelial cells of the *somatic mesoderm* (Fig. 2276, No. 6) near the *middle plate* (No. 5) evaginate on both sides, and form a cord of cells parallel with the notochord; at several points along the cephalic extremity of this longitudinal cord of cells it retains its connection with the lining cells of the cœlom (abdominal cavity) by short transverse cords of cells. Soon the cell cords are hollowed out, and thus are formed the segmental or Wolffian duct (Fig. 2277, *W*), which passes caudad and empties into the *cloaca* (*Cl*), and several short transverse *tubules* (Nos. 1, 1, 1), opening at one end into the cœlom and at the other extremity into the Wolffian duct. The transverse tubules in the immediate neighborhood of their cœlomic extremities are evaginated by a tuft of capillary blood-vessels from a branch of the adjacent axial blood-vessel (aorta), so that a series of *glomeruli* are formed. Through the physiological activity of the cells of the glomeruli the urinary constituents are eliminated in the Anamnia from the blood and passed along the transverse tubules into the Wolffian duct and cloaca and thence evacuated from the body. It is thus seen that the transverse tubules and their glomeruli constitute a segmental primitive kidney (pronephros). This pronephros (Fig. 2277, Nos. 1, 1, 1), though functional in Cyclostomes, Teleosts, and larval Amphibians, is vestigial in Selachians, Reptiles, Birds, and Mammals, and never functionates as a urinary organ; it soon gives place to the more important *mesonephros* (Fig. 2277, Nos. 2, 2, 2, 2).

Simultaneously with the segmentation of the paraxial mesoderm (Fig. 2276, No. 9) into the somites, the *middle plate* undergoes segmentation, and each segment is called a *nephrotome*. In the lower vertebrates each nephrotome is hollow and is formed by evagination of the cœlomic mesothelium; but in Reptiles, Birds, and Mammals the nephrotomes are at first solid cords of cells which subsequently become hollowed out and converted into a series of transverse, short canals situated behind, caudad of, the pronephros. They soon acquire connection with the previously formed Wolffian duct. Collectively they constitute the Wolffian body or *mesonephros*. At the cephalic end of the Wolffian duct, the now atrophied transverse tubules and glomeruli of the pronephros are still in connection with it. Embryologists usually compare the mesonephros with its Wolffian duct to a comb, the duct corresponding to the back of the comb, and the short transverse tubules representing the teeth.

In the further development of the mesonephros each transverse tubule becomes somewhat saccular midway between its two extremities, and then the sacculated portion is invaginated by a tuft of capillary blood-vessels derived from an arterial branch of the aorta. The invaginating tuft of capillaries is known as a Malpighian tuft, while the invaginated portion of the transverse tubule is called the Malpighian capsule; the two together constitute a primitive Malpighian body, analogous with the Malpighian bodies of the permanent kidney or metanephros. By the development of secondary tubules and Malpighian bodies the complexity of the mesonephros is greatly increased.

In those vertebrates in which the pronephros attains to a temporary functional activity, as in Cyclostomes, Teleosts, and Amphibians, the mesonephros appears relatively late; on the contrary, in those animals in which the pronephros remains rudimentary, as in Sharks, Reptiles, Birds, and Mammals, the mesonephros is developed early.

In the Anamnia (Fishes and Amphibians) the mesonephros not only acquires relations with the sexual apparatus, but also functionates as a urinary organ. Hence in these animals there is no metanephros. In the Amnia (Reptiles, Birds, and Mammals) the mesonephros functionates as a urinary organ only a short period during embryonic life; it undergoes profound retrograde and adaptive changes soon after its formation and enters into the exclusive service of the sexual apparatus, serving as channels to conduct the sexual cells from the germinal glands in the male, and becoming entirely vestigial in the female (parovarium and paroöphoron).

The transverse tubules of the mesonephros are divisible, in man, into an anterior or cephalic series and a posterior or caudal set. The former are the *sexual* set, and the latter become vestigial as the paradidymis and vas aberrans (homologous with the paroöphoron of woman) (Fig. 2279).

In the Amnia the permanent urinary organ is the metanephros. While the mesonephros and its Wolffian duct are temporarily functionating as a kidney, an evagination occurs from the caudal extremity of the duct.

This evagination soon lengthens into a tube (Fig. 2277, *Met*), which extends cephalad, toward the caudal part of the mesonephros. The cephalic end of the rudimentary metanephros branches freely to form a number of smaller tubes. The surrounding undifferentiated mesodermic cells form enveloping connective and vascular tissue. The blind end of each little tube becomes dilated and then invaginated by a tuft of capillary blood-vessels so that Malpighian bodies are formed analogous to those in the pro- and mesonephros. The tubules, owing to excessive growth in length, become tortuous and convoluted. The stalk of the diverticulum becomes the *ureter*, while the dilated part from which the branches are given off differentiates into the pelvis of the kidney with its infundibula and calyces.

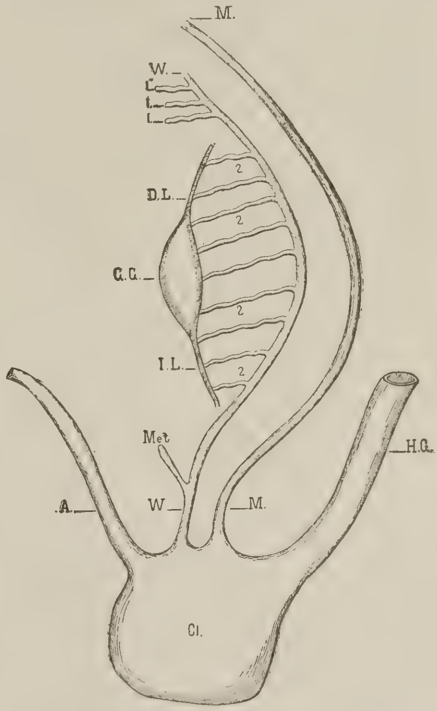

FIG. 2277.—Early Embryonic Condition of the Urogenital System. Diagrammatic. Sex undifferentiated. *A.*, Allantois; *Cl.*, cloaca; *H. G.*, hind gut; *W.*, Wolffian duct; *M.*, Müllerian duct; 1, 1, 1, pronephros; 2, 2, 2, 2, mesonephros (Wolffian body); *Met.*, metanephros (rudimentary permanent kidney); *G. G.*, germinal gland; *D. L.*, diaphragmatic ligament; *I. L.*, inguinal ligament.

Shortly after the formation of the mesonephros another tube (*Müllerian duct*) appears (Fig. 2277, *M.*). It lies close to the outer side of the Wolffian duct and parallel with it. It arises by evagination of the mesothelium of the cœlom in the form of a solid cord of cells and later acquires a lumen. The cephalic end of the duct, near the pronephros, maintains a communication with the cœlom by means of an expanded funnel-shaped mouth, while the caudal part empties into the cloaca. Its lower segment becomes closely associated with its fellow of the opposite side and with the two Wolffian ducts, thus forming the *genital cord*. The cloacal segments of the Müllerian ducts fuse early into a common tube, except in the Monotremes, where they remain permanently separate and empty into the urogenital sinus (Fig. 2278, *M.*). In all other Mammals they fuse to a greater and greater degree in the ascending mammalian scale. Varying degrees of reversion to the more primitive types occur as instructive anomalies in human anatomy.

In the ascending vertebrate scale, the Wolffian duct first appears in Cyclostomes, the Müllerian duct in Elasmobranchs, and the metanephric ureter in Reptiles.

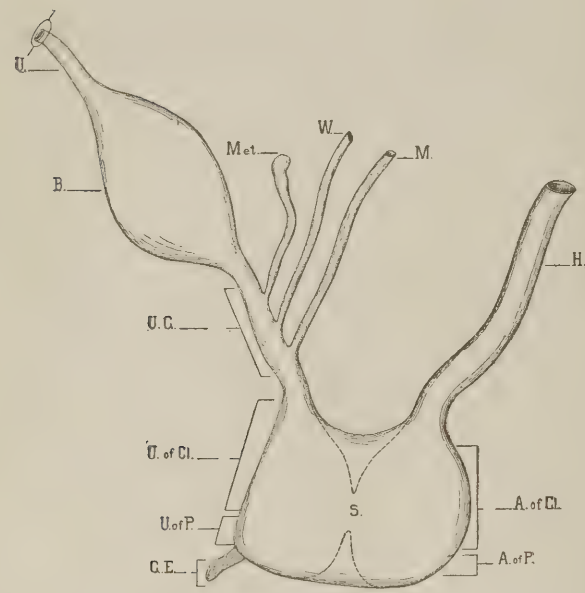

FIG. 2278.—Embryonic Condition of the Urogenital System Later than that Represented in Fig. 2277. Diagrammatic. The allantois has differentiated into the urachus (*U.*), bladder (*B.*), and urogenital sinus (*U. G.*). The proctodeum has appeared and, with the cloaca, is undergoing subdivision by the formation of the perineum (*S.*). *U. of Cl.*, Urogenital part of the cloaca; *U. of P.*, urogenital part of the proctodeum; *A. of P.*, anal part of the proctodeum; *A. of Cl.*, anal part of the cloaca; *H. G.*, hind gut; *G. E.*, genital eminence; *Met.*, metanephros (permanent kidney); *W.*, caudal part of the Wolffian duct; *M.*, caudal part of the Müllerian duct.

This is a convenient place to state that the intra-embryonic portion of the allantois—in other words, that portion extending from the umbilicus to the cloaca—becomes differentiated into three segments as follows: The middle part dilates to form the *bladder* (Fig. 2278, *B.*), the umbilical portion becomes the *urachus* (*U.*), and the cloacal segment differentiates into the *urogenital sinus* (*U. G.*).

Through unequal growth of the parts the Wolffian and Müllerian ducts shift their positions from the cloaca to the urogenital sinus (Figs. 2277 and 2278), and also the duct (ureter) of the metanephros (permanent kidney) shifts its position from the Wolffian duct, first, to the urogenital sinus (Fig. 2278, *Met.*), and, finally, to the base of the bladder (Fig. 2279, *Met.*). Only in the Monotremes, among Mammals, do the ureters open permanently into the urogenital sinus.

In the twelfth week of the embryo the urogenital sinus acquires thick muscular walls, and the lining epithelial tube evaginates into the muscular tissue in the form of little sacs, the lining cells of which differentiate into secreting epithelium. Thus is formed the *prostate gland* enveloping the urogenital sinus or, as it is now designated, the *prostatic urethra.* The prostatic urethra is homologous with the *urethra* and the proximal part of the *internymphal space* of the adult female (Fig. 2280). The musculo-glandular part of the prostate is possibly homologous with the musculo-glandular part of the uterus. In this connection it is interesting to note that castration leads to atrophy of the prostate and removal of the ovaries induces atrophy of the uterus.

While the Müllerian duct is developing, a thickening of the mesothelial cells of the cœlom occurs close to the ventromesial portion of the mesonephros, thus forming an elongated swelling (*germinal ridge*) on the wall of the cœlom. By the proliferation of the mesoblastic tissue beneath the mesothelial cells the germinal ridge is still further enlarged, ultimately forming the *germinal gland* (Fig. 2277, *G.G.*). The gland becomes gradually pinched off from the mesonephros as the embryo grows, though still maintaining a connection with the vestige of this body by a fold of peritoneum (mesorchium or mesovarium).

In the differentiation of the male from the abovementioned indifferent fundiments the following changes take place, viz.: columns of mesothelial cells of the germinal gland are evaginated into the mesoblastic tissue as *sperm tubes,* or sexual cords. By growths of the mesoblastic tissue the sexual cords are divided into roundish, follicle-like masses, which become hollowed out to constitute the *seminal ampullæ.* These, by further growth, are transformed into *seminiferous tubules* (Fig. 2288, No. 6), containing, among many smaller cells, a less number of large *sperm cells* (spermatogones) which develop into spermatozoa. By further transformations the characteristics of the adult testicle proper, or *didymis* (Fig. 2287, *Tunica vag. Vis.*), are developed. At the same time marked changes occur in the *mesonephros,* for from the sexual series of the transverse tubules of this organ cords of cells *penetrate* the germinal glands and fuse with the seminiferous tubules. The conversion of the cell cords into tubes produces the *coni vasculosi* of the *head* or globus major (Fig. 2288, No. 2; Fig. 2279, No. 8; Fig. 2287) of the epididymis, which are homologous with the parovarium of the female; the *vasa efferentia* (Fig. 2288, No. 3); the *rete testis* (No. 9); and the *vasa recta* (No. 7). The cephalic part of the Wolffian duct (from the mesonephros, Fig. 2277) develops into the *body* (Fig. 2288, No. 10) and *tail* or globus minor (Fig. 2288, No. 10; Fig. 2279, Nos. 4, 4, 4, 4) of the epididymis, while the caudal portion becomes the *vas deferens* (Fig. 2288, No. 12; Fig. 2279, W.) (homologous with the duct of Gärtner of the female). Near the extreme caudal portion of the Wolffian duct an evaginated pouch appears which develops into the *seminal bladder* (Fig. 2279, *V.*) and its duct. Caudad of this evagination the Wolffian duct becomes the *ejaculatory duct.*

The pronephros degenerates in both sexes into a vestige, *the stalked hydatid,* or hydatid of Morgagni, a little pedunculated sac attached to the upper part of the epididymis in the male (Fig. 2279, No. 7; Fig. 2287). The non-sexual, caudal series of mesonephric tubules likewise give rise to a vestigial structure, the paradidymis (Fig. 2279, Nos. 3, 3, 3), or organ of Giraldès, homologous with the paroöphoron in the female, lying among the convolutions of the tail of the adult epididymis. Primitively the germinal glands were arranged segmentally and extended along a greater number of somites as in Amphioxus at present. Each segment discharged its germ cells into an atrium and thence by an atriopore to the external water where impregnation took place; or, as in the higher Cyclostomes, the spermatozoa were discharged into the cœlom and made their way through the urogenital pores into the urogenital sinus and thence to the water. Then in Elasmobranchs the advance took place by which the spermatozoa are discharged along the Wolffian duct, a condition which persists in all the higher vertebrates.

In the male the Müllerian duct becomes vestigial throughout nearly its whole extent. Its cephalic extremity persists as the sessile or unstalked hydatid (Fig. 2279, No. 6), and is homologous with the fimbriated extremity of the Fallopian tube in the female. It is a small vesicle attached to the cephalic part of the testicle. The caudal part of the duct becomes the *uterus masculinus* (Fig. 2279, *M.*), and is homologous with the vagina and uterus. Should the intervening part of the duct persist in a patulous condition it is known as the *duct of Rathke* and is homologous with the oviduct of the female.

Testes. The testes in some Mammals, as in *Manis* among the Edentates, are subintegumental and lie in the inguinal canal. They remain normally in the abdomen in many Mammals, as in Monotremes, most Edentates, and the Elephant.

During ontogeny the testes arise in the same relative position as the ovaries in Mammals. Whereas normally, in man, the ovary never passes further caudad than the pelvis, the testis usually passes out of the abdomen through the *inguinal canal* into an evagination of the abdominal wall (*scrotal sac*) lined by evaginated peritoneum (*tunica vaginalis*). In some of the lower Mammals the two scrotal sacs continue separate, but in man they unite by a median raphe into a single scrotum. In man and most Mammals the testes remain permanently in the scrotum by reason of the great reduction in size of the inguinal canal. Through arrest of development man's testicles may present all degrees of reversion in position to that of more primitive types.

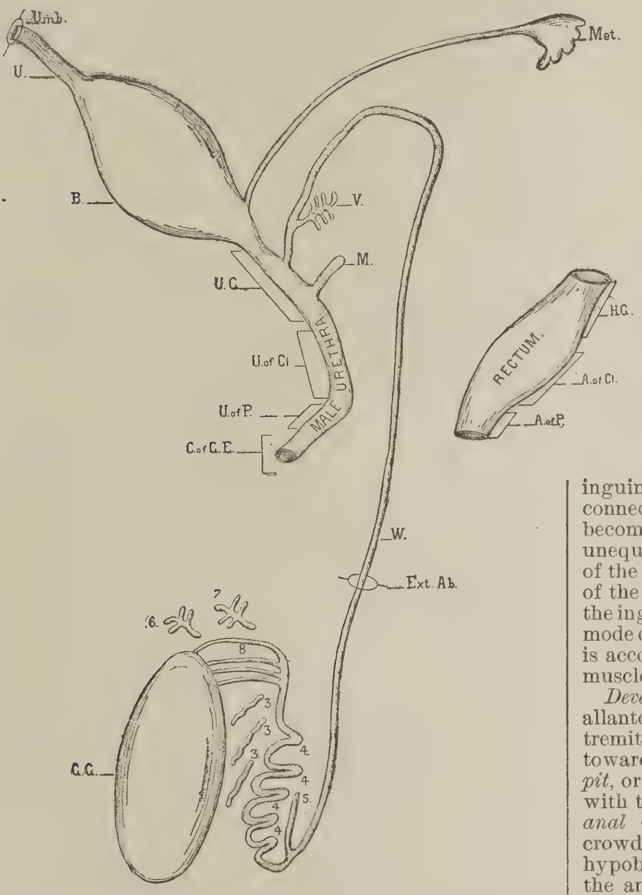

FIG. 2279.—Diagrammatic Representation of the Adult Male Urogenital System. Illustrating especially the embryonic elements that enter into the formation of the male urethra, the epididymis, and the rectum. The testicle (*G. G.*) and its related but much modified mesonephros (3, 3, 3, 4, 4, 4, 4, 5, 8) have descended from the abdominal cavity into the scrotum. *Umb.*, Umbilicus; *U.*, urachus; *B.*, bladder; *U. G.*, prostatic urethra (urogenital sinus); *U. of Cl.*, together with *U. of P.*, form the membranous urethra (*U. of Cl.* is the urogenital part of the cloaca, and *U. of P.* is the urogenital part of the proctodeum); *C. of G. E.*, spongy urethra (canal of the genital eminence); *Met.*, permanent kidney (metanephros) and ureter; *V.*, vesicula seminalis; *M.*, uterus masculinus (distal vestige of Müllerian duct); *W.*, vas deferens (Wolffian duct); *Ext. Ab.*, external abdominal ring; 6, sessile hydatid (proximal vestige of Müllerian duct); 7, stalked hydatid (vestige of pronephros); 8, globus major of the epididymis; 4, 4, 4, 4, body and globus minor of the epididymis continued into the vas deferens (*W.*); 8, 4, 4, 4, 4, sexual adaptations of the mesonephros; 5, vas aberrans (vestige of mesonephros); 3, 3, 3, paradidymis (non-sexual vestige of mesonephros); *G. G.*, testicle or didymis (germinal gland); *A. of P.*, anal part of proctodeum; *A. of Cl.*, anal part of cloaca; *H. G.*, hind gut.

Compare the male urethra with the female urethro-internymphal channel (Fig. 2280, 1, 2, 4, 5, 6).

The descent of the testes is a late development peculiar to Mammals. Primitively it was a periodic phenomenon occurring in the adult. At present, in the hedgehog, the testes retain their primitive cœlomic position up to the rutting period; but as the rut approaches they come to lie in evaginable portions of the abdominal wall in the inguinal region. After the rutting season they return to their abdominal position.

In their descent the testicles necessarily drag after them their attached structures, such as the spermatic artery and veins, the vas deferens, lymphatics, and nerves, all bound together by connective tissue, and thus constituting the *spermatic cord* (Fig. 2287, *Funiculus Sperm.*).

Mode of descent of the testicle. The descent of the testicle is a striking feature of its development. From the mode of development of the mesonephros and its ventro-median genital gland, they both are situated behind the peritoneal sac. Increasing in size they invaginate the sac and apparently project into the abdominal cavity, being held in position by peritoneum (mesorchium). Since the mid-kidney is the most conspicuous part of the projecting mass, the portion of the mesorchium extending to the diaphragm is called the *diaphragmatic ligament* (Fig. 2277, *D. L.*) of the kidney and the segment extending to the inguinal region is designated its *inguinal ligament* (Fig. 2277, *I. L.*). When the primitive kidney has become incorporated with the testicle as a part of its excretory apparatus, the inguinal ligament connects exclusively the testicle with the inguinal region. The inguinal ligament contains between its peritoneal folds connective tissue and unstriped muscular fibres, which become the *gubernaculum testis.* It is through processes of unequal growth of the body of the fœtus and the tissues of the ligament that the testicle is displaced from the side of the lumbar spine to the false pelvis and thence through the inguinal canal into the scrotum. The most primitive mode of descent is that observed in Insectivores, where it is accomplished through the agency of the cremasteric muscle.

Development of the External Genital Organs.—While the allantois is growing there is formed, near the caudal extremity of the embryo, a *surface depression* extending toward the cloaca. This depression is known as the *anal pit,* or *proctodeum.* The anal pit, though communicating with the surface, is partitioned off from the cloaca by the *anal membrane.* This membrane has its mesoblast crowded aside by the anal epiblast and the cloacal hypoblast growing together. By the breaking down of the anal membrane the cloaca is enlarged and communicates with the surface. Should the membrane fail of normal absorption a child would be born with *imperforate anus.*

In Fishes, Amphibians, Reptiles, Birds, and the lowest Mammals (*Monotremes*), the cloaca is a permanent structure through which the intestinal, urinary, and testicular secretions are voided. Man evolves first to and then beyond the cloacal state. In all mammals above Monotremes, and therefore in man, the *enlarged cloaca* (cloaca-proctodeum) undergoes division about the eighth week into a dorsal or *anorectal* cloaca (rectum and canal of the anus) and a ventral or *urogenital* cloaca (Fig. 2278, *U. of Cl.*, *A. of Cl.*, *U. of P.*, *A. of P.*). This division is accomplished by the growth and fusion of three ridges, one of which appears at the point of union of the gut and the urogenital sinus, while the other two extend, one from each lateral wall of the cloaca. The septum formed by the growth and fusion of the three ridges continues to thicken, especially near the surface, until it forms a pyramidal mass of tissue, called the perineum, or, preferably, *perineal body* (Fig. 2278, *S.*), since the urogenital portion of the outlet of the pelvis has been designated as the perineum. The urogenital portion of the cloaca-proctodeum develops into the *membranous urethra* of the adult male.

Just ventral to the aperture of the cloaca (cloaca-proctodeum), about the sixth week, appears the *genital eminence* (Fig. 2278, *G. E.*, Figs. 2281 and 2282), and soon both cloacal aperture and the eminence are surrounded by the *genital ridges.* About the eighth week a groove (*genital groove*) appears on the under or cloacal surface of the genital eminence in *continuity with* the urogenital cloaca-proctodeum, and therefore with the urogenital sinus (Figs. 2279, 2281, and 2282). The groove becoming deeper is bounded laterally by projecting folds (Figs. 2281 and 2282) of skin (*genital folds*). For descriptive purposes, later, the genital folds may be divided into intra- and extraperineal portions. It is due to the growth of the perineal body that the anus is pushed entirely out of the field of the developed genital ridges (scrotum). The external genital organs of the male represent a further stage of development than the corresponding female parts. The genital eminence early acquires a knob-like extremity which develops into the *glans penis* (homologous with glans clitoridis) and its enveloping *prepuce* The rest of the genital eminence, exclusive of the genital groove and genital folds, becomes developed into the corpora cavernosa of the clitoris or penis, and their enveloping tissues. The penis has well-marked intra- and extraperineal segments.

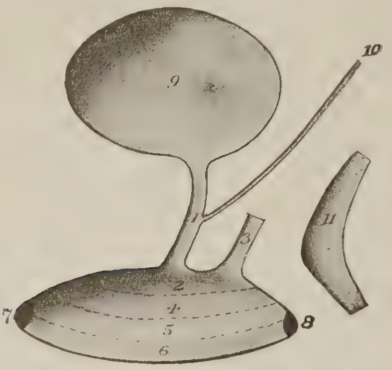

FIG. 2280.—Sagittal Section through the Adult Vulva, Vagina, Urethra, etc. Medial surface. Diagrammatic. 1, Urethra (proximal part of the urogenital sinus); 2, distal part of the urogenital sinus or proximal part of the internymphal cleft; 4, stratum of the internymphal cleft corresponding to the urogenital cloaca; 5, stratum of the cleft corresponding to the urogenital proctodeum; 6, stratum corresponding to the genital groove of the genital eminence; 2, 4, 5, 6, mesial surface of the right boundary of the internymphal cleft; 7, glans clitoridis; 8, fourchette; 9, bladder; 10, duct of Gärtner (persistent Wolffian duct): 3, vagina (enlarged Müllerian duct); 11, rectum; 1, 2, 4, 5, 6, urethro-internymphal channel and homologous with the entire male urethra. Compare with Fig. 2279.

In both sexes, by further growth, the genital folds are extended along the sides of the outlet of the urogenital portion of the proctodeum dorsad toward the perineal body, so that a large part of the groove is caudad from, but continuous with, the outlet of the proctodeum (Fig. 2282). This portion of the genital folds may be spoken of as the *intraperineal* parts By ventrad extension of the genital eminence and its glans penis, the *extraperineal* parts of the penis are formed. The extraperineal development of the genital eminence in the female is so slight that it scarcely exists,—in her the eminence is essentially intraperineal. In the female, through lack of fusion of the segments, the intraperineal parts form the *nymphæ* with their contained *bulbi vestibuli* and *pars intermedia* as the lateral boundaries of the genital groove, the *fourchette* as the dorsal boundary, and the *glans clitoridis* as the ventral boundary of the *genital groove.* The genital groove, caudad from the proctodeum, becomes in the adult the most caudal morphological element of the internymphal cleft (Figs 2280, 2282). In the male development proceeds further than the stage represented in Fig. 2282. The genital folds bordering the outlet of the proctodeum fuse at their free margins and form the *intraperineal* portions of the corpus spongiosum (bulb and portion of the body), the intraperineal urethra, and the enveloping skin. This intraperineal portion of the corpus spongiosum is homologous with the bulbi vestibuli and pars intermedia of the female. By ventrad extension of the genital eminence and its genital folds and groove, and fusion of the fold margins, the extraperineal (pendulous) portion of the corpus spongiosum and its urethra are formed. The distal opening of the urethra is the *meatus urinarius.* It is generally stated in works on embryology, to the confusion of students of homology, that the urogenital sinus of the sexually undifferentiated embryo is homologous with the prostatic and membranous urethra of the male and with the vestibule of the female. But this certainly is incorrect. It seems to us far more in conformity with the facts to say that the *embryonic urogenital sinus* (Figs. 2278 and 2279, *U. G.*), plus the *urogenital cloaca* (*U. of Cl.*), plus the *urogenital proctodeum* (*U. of P.*), and plus the *genital groove* (*G. E.*, or *C. of G. E.*), differentiate into the *male urethra* from the neck of the bladder to the meatus urinarius on the one hand, or into the *female urethra and internymphal cleft* on the other hand (Fig. 2280). So that the male urethra is homologous with the urethro-internymphal space of the female.

The *vestibule* in human anatomy is described as the space extending from the glans clitoridis to the ostium vaginæ and between the nymphæ. The vestibule as thus defined is useless for studying homologies. The *whole space* between the nymphæ extending from the glans clitoridis (Fig. 2280, No. 7) to the fourchette (Fig. 2280, No. 8) must be considered. This internymphal space of the female is formed from several (four) distinct morphological elements, as follows—viz., a *part* of the urogenital sinus of the embryo (Fig. 2280, No. 2), urogenital cloaca (4), urogenital proctodeum (5), and genital groove (6).

That the most caudal part of the internymphal space corresponds to the spongy urethra is illustrated, among other things, by the fact that the ducts of Bartholin's glands open on the mesial surfaces of the nymphæ external to the hymen, just as the ducts of Cowper's glands open into the spongy urethra. The genital ridge differentiates into the mons veneris, and into two prominent pouches on either side of the penis, which become fused, by a median *raphe,* into the scrotum (homologous with labia majora of female).

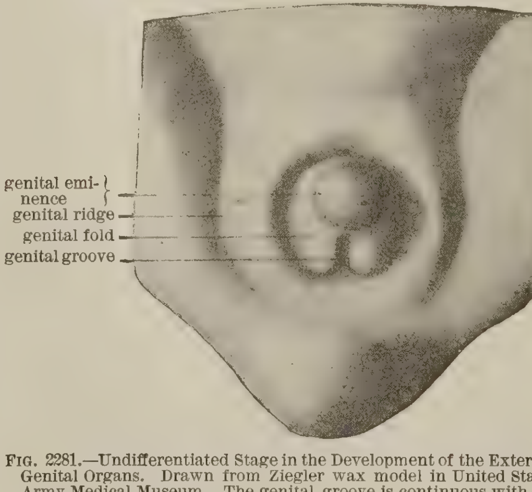

FIG. 2281.—Undifferentiated Stage in the Development of the External Genital Organs. Drawn from Ziegler wax model in United States Army Medical Museum. The genital groove is continuous with the undivided cloaca-proctodeal cavity.

By consequence of evaginations from the genital groove there are formed the glands of Cowper (homologous with the glands of Bartholin).

The differentiation of the genital ridges in the female into the *labia majora* enlarges the internymphal space into the interlabial space. In adult human anatomy the *vulval cleft* usually means the whole interlabial space. From the fact that the external fundiments of the sexual organs are exactly alike in both sexes, it is evident why, through abnormal ontogeny, forms come under observation occasionally which make it very difficult to decide whether they are male or female. These are the so-called cases of *hermaphroditism*. They arise either from the excessive development of certain fundiments or the interrupted development of other parts, in both the male and female. The male is most subject to those malformations which have led to the supposition that there may be hermaphroditism in man. They are due to the fact that the normal processes of fusion are interrupted in association with the interrupted development of other parts. For example, the genital ridges (Fig. 2282) may fail to unite into a scrotum and will simulate the labia majora of the female; the resemblance may be heightened by the failure of the testes to leave the abdominal cavity; and, further, the penis may be so rudimentary as closely to resemble a clitoris. Again, as I have seen, there may be a very noticeable depression between what seem to be incompletely fused genital folds (Fig. 2282) and every suggestion of a rudimentary *vagina*. The individual, though an adult, may be lacking in a growth of hair on the face; and, lastly, the mammary glands, as I have seen, may be as well developed as a woman's. But in spite of all these misleading features, the presence of *testes* in the abdominal cavity would stamp the individual as a man. In a case of this kind, unless a microscopic examination should reveal a seminal discharge, it would require an autopsy to ascertain whether testes or ovaries were in the abdomen.

Lack of fusion of the genital folds leads to various degrees of a pathological condition known as *hypospadias*.

Copulatory organs of various forms occur amongst the vertebrates, often morphologically distinct from one another.

A specially modified portion of each pelvic fin (clasper) occurs in male Sharks. Amongst the Teleosts the male Girardinus has the terminal portion of the anal fin modified for holding the female, and in many Cyprinoids the anal fin has modifications for a similar function. A marked swelling of the lips of the cloaca occurs in certain Amphibians, as the Urodeles, during the breeding season, by which internal impregnation may take place, but only in male Gymnophiona is a definite copulatory organ present in the form of an eversible cloaca, which is regulated by a well-developed musculature. Among Reptiles two kinds of copulatory organs exist, the one being seen in Crocodiles and Chelonians, and the other in Snakes and Lizards. In the former the organ is single and is a thickened portion of the ventral wall of the cloaca which is regulated by muscles and is protrusible. It consists of erectile tissue and has its dorsal surface grooved for the reception of the seminal fluid from the seminal ducts.

In Snakes and Lizards two copulatory sacs lie under the skin at the root of the tail and outside of the cloaca, which are regulated by a well-developed musculature and can be protruded through the cloacal opening and withdrawn. A spiral groove, for the transmission of semen, extends along each everted sac.

In most Birds the semen is expelled through a noneversible cloaca, but in many, copulatory organs are present similar to those of Crocodiles and Chelonians.

In the males of all Mammals except the Monotremes, Marsupials, and some Edentates the *penis* consists of two *corpora cavernosa* attached proximally to the *ischia*, and a central portion, the *corpus spongiosum*, perforated by the urethral canal and expanded at the extremity to form the glans. The penis of Monotremes, decidedly reptilian, is situated in the cloaca and is indirectly in relation with the seminal ducts through the urogenital sinus. It consists of an unpaired corpus cavernosum (there is no corpus spongiosum) perforated with a canal in continuity with the urogenital sinus and the seminal ducts. It is only loosely surrounded by the mucous membrane of the cloaca, has a well-developed musculature, and can be protruded through the cloacal aperture.

The penis sheath, in Marsupials, opens directly on the surface of the body ventral to the anus, on account of the growth of the perineum. The two openings are surrounded by a common sphincter muscle. The erectile tissue is paired (two corpora cavernosa), but unconnected with the ischia.

The penis of Insectivores and Rodents, among Placental Mammals, approaches nearest that of Marsupials. In the ascending scale of Mammals the opening of the penis sheath is separated more and more from the anus and the penis comes more and more to a ventral position, attaining a horizontal and fixed position along the abdomen. In the Apes the organ becomes more or less free from the body wall at its distal end, while in Man the whole of the distal end is free and the penis sheath forms a double integumentary tube-like investment (prepuce) over the glans.

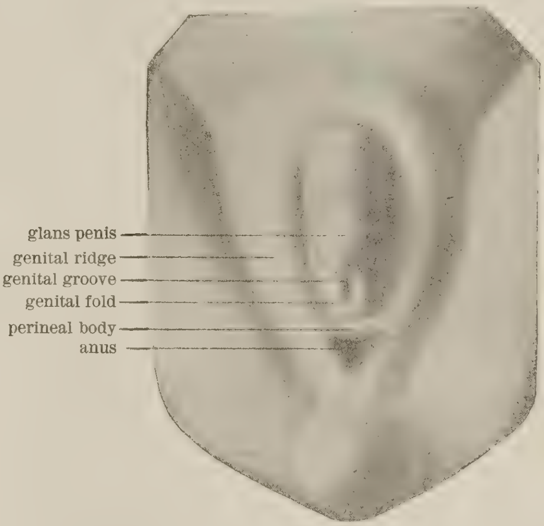

FIG. 2282.—Early Embryonic Stage of Male External Genital Organs. Drawn from Ziegler wax model in United States Army Medical Museum. Genital eminence projects so far dorsad and caudad as to conceal the genital folds and genital groove, which are continued to the under surface of the glans penis. The perineal body has formed and separates the cloaca-proctodeal cavity into a dorsal part having its outlet at the anus, and a ventral part having outlet at the genital groove, in virtue of the fact that the genital folds have extended dorsad and united to form the fourchette just ventrad of the perineal body. It will thus be observed that the genital folds and genital groove are practically divisible, even at this early stage, into intraperineal (root of penis) and extraperineal (pendulous part of penis) segments.

During ontogeny, in Marsupials and Placental Mammals, the penis passes through stages that resemble successively those which are permanent in Crocodiles and Monotremes.

CHRONOLOGY OF UROGENITAL DEVELOPMENT.—*Third Week.*—About this time the Wolffian duct and pronephros are recognizable, the nephrotomes begin to develop and also the allantoic stalk appears.

Fifth Week.—The germinal ridges and the Müllerian duct appear and the fœtus is two-fifths of an inch (1 cm.) long.

Sixth Week.—The genital eminence, folds, groove, and ridge appear.

Seventh Week.—The mesonephros reaches its maximum development.

Eighth Week.—The caudal portions of the Müllerian ducts fuse, and the allantois presents a spindle-shaped dilatation in its middle forming the bladder.

Ninth Week.—The cloaca is divided into two parts. The permanent kidney has characteristic features. The testes are distinguishable from ovaries. The fundiments of the external genitals begin to show distinctions of sex.

The fœtus is one inch long (25 mm.) and weighs about 16 gm. (half ounce).

Third Month.—Prostate gland begins to develop. The union of the testes with the canals of the Wolffian body is complete. The testes are in the false pelvis. Fœtus is 2¾ inches long (7 cm.) and weighs 125 gm. (four ounces).

Fourth Month.—Sexual distinctions in external genitals are well marked. The genital groove is closed. The scrotum is formed, as also the prepuce. The prostate is well formed. Fœtus is 5 inches (13 cm.) long and weighs 240 gm., or 7¾ ounces.

Seventh Month.—The testes are at the internal abdominal ring. Fœtus 14 inches (36 cm.) long and weighs 3 pounds (about 1.5 kgm.).

Eighth Month.—The testes are in the inguinal canal. Fœtus 16 inches (41 cm.) long. Weighs 4 to 5 pounds (about 2 to 2.5 kgm.).

Ninth Month.—The testes are in the scrotum. Fœtus 20 inches (50 cm.) long. Weighs 6 to 7 pounds (about 3 to 3.5 kgm.).

ADULT GENITAL ORGANS.—The *male urethra* is the urogenital canal extending from the bladder to the extremity of the penis (Figs. 2279 and 2283). In the flaccid state it forms a double curve, but when erect it presents a single curve with the concavity ventrad. It is about 7 inches (19 cm.) in length when flaccid, but during erections greatly elongated. It is divided in a prostatic portion (1¼ in. or 32 mm. long), membranous part (three-quarters of an inch or 20 mm. long), and a spongy portion (5 in. or 14 cm. long). The urethra, except during the passage of urine or semen, has the ventral and dorsal surfaces in contact. The prostatic portion (Fig. 2283, No. 3) is spindle shaped and is the most dilatable and widest part of the canal. A narrow longitudinal ridge (*verumontanum*), three-quarters of an inch (20 mm.) in length, exists upon the dorsal wall. It is formed by the projecting mucous membrane and contains muscular and erectile tissue. It serves, when distended, to prevent the semen passing back into the bladder. There is a slightly depressed fossa (*prostatic sinus*) on either side of the verumontanum. A depression (*uterus masculinus*) exists at its distal part (Fig. 2279, *M*). It is a *cul-de-sac* about a quarter of an inch (6 mm.) in length extending dorsocephalad in the substance of an organ (*prostate gland*), which envelops the prostatic urethra (Fig. 2283, No. 3). Its walls are composed of mucous, connective, and muscular tissue, and the ducts of numerous small glands open upon its mucous surface. The uterus masculinus is homologous with the vagina and uterus of the female. The membranous urethra (Fig. 2283, No. 2) is the narrowest part of the canal except at its termination in the penis. Its ventral surface is concave and is placed about an inch dorso-caudad from the subpubic arch. Its dorsal surface is separated from the rectum by the perineal body (Fig. 2283, No. 5).

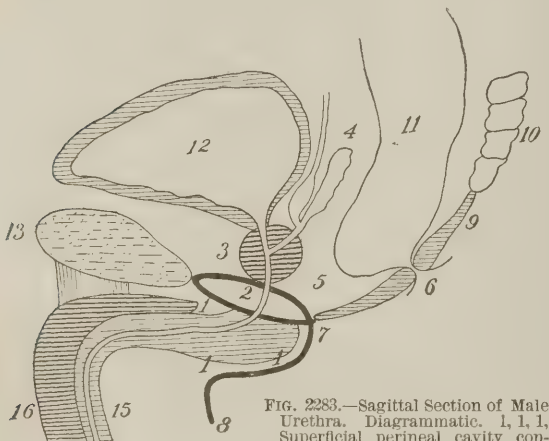

FIG. 2283.—Sagittal Section of Male Urethra. Diagrammatic. 1, 1, 1, Superficial perineal cavity containing the intraperineal segments of the corpora cavernosa, corpus spongiosum, etc. ; 2, deep perineal cavity containing the membranous urethra and bounded by the two layers of the deep perineal fascia (triangular ligament of the urethra) ; 3, prostate gland transmitting the prostatic urethra ; 4, vesicula seminalis and vas deferens emptying through the ejaculatory duct into prostatic urethra; 5, site of perineal body ; 6, anal portion of rectum (11) passing through the sphincter ani muscle (9) ; 7, central tendon of perineum whence starts Colles' fascia to continue into the dartos (8) of the scrotum ; 10, coccyx ; 12, bladder ; 13, symphysis pubis ; 15, extraperineal portion of corpus spongiosum ; the spongy urethra is seen traversing the corpus spongiosum and terminating at the meatus urinarius in the glans penis (14) ; the bulb of the corpus spongiosum is seen in the superficial perineal cavity, resting against the perineal layer of triangular ligament ; the prostate is in the pelvic cavity, resting against the pelvic layer of triangular ligament ; 16, extraperineal portion of corpus cavernosum ; extending between the symphysis and corpus cavernosum is seen the suspensory ligament of the penis.

The spongy urethra (Fig. 2283, No. 15) is the longest. Its calibre is intermediate between the other segments, and uniform except at either extremity. For half an inch (13 mm.) behind the terminal opening it is dilated and forms the *fossa navicularis*, while behind, for an inch (25 mm.), it widens in every direction and is called the *pars bulbosa.*

The urethra is composed of three coats: mucous, areolar, and muscular. The inner, or mucous, coat is continuous at its proximal end with the mucous coat of the bladder and at its distal end with the integument of the penis. It is also continuous with the ducts of the several glands opening into it. Its epithelial lining consists of columnar cells, except at the distal opening, where the cells are squamous. The mucous coat is arranged in longitudinal folds in the membranous and spongy portions when the urethra is empty. The orifices of numerous mucous glands occur on the surface of the mucous coat, especially on the spongy portion, while the glands themselves (glands of Littré) are situated in the submucous connective tissue. The orifices are directed distally and vary in size, and some may easily intercept the point of a small instrument. One of these orifices, much larger than the rest (*lacuna magna*), is situated in the fossa navicularis on its dorsal surface, about half an inch (13 mm.) or so from the outlet.

The areolar coat is rich in elastic fibres, and its interstices are plentifully supplied with convoluted vessels which serve the purpose of erectile tissue. The outer or muscular coat consists of two layers of unstriped muscular fibres, the outer being longitudinal and the inner circular.

The Perineum and Penis.—The male perineum (Fig. 2284), or urogenital region of the outlet of the pelvis, is bounded by the subpubic arch (Nos. 1, 1), the pubo-ischiatic rami (No. 4), the ischial tuberosities (No. 7), and the transversus perinei muscles. The arch and rami present two lips and an intermediate space. The transversus perinei muscles, one on either side, arise laterally from the ischial tuberosities and are inserted medianly into the central tendinous point (No. 6) of the perineum. Each is innervated by the perineal branch of the internal pudic nerve. Their action is to fix the central tendinous point of the perineum.

Extending from fixed attachments—viz., from the dorsal (posterior) border of the muscles and the central tendon, along their deep (pelvic) surfaces, and thence along the deep (pelvic) lips of the pubo-ischiatic rami, and subpubic arch—is a triangular-shaped fascia (Fig. 2284, No. 5). At the points of attachment the fascia is single, but across the triangular interval which it occupies it divides into two layers, a superficial or perineal layer and a deep or pelvic one. Between the two layers, therefore, exists a space called the *deep perineal cavity* (Fig. 2283, No. 2), which contains a number of structures, viz., the membranous portion of the urethra (whence the name of triangular ligament of urethra for the double-layered fascia), Cowper's glands, the compressor urethræ muscle, subpubic ligament, the internal pudic vessels, the dorsal nerve and vein of the penis, the artery and nerve of the bulb, and a plexus of veins, all bound together by very delicate connective tissue.

The deep or pelvic layer of the triangular ligament is continuous with the pelvic fascia. The superficial layer is the *deep floor* of a second perineal cavity, *the superficial perineal cavity* (Fig. 2283, Nos. 1, 1, 1). The perineum has another important fascia (superficial perineal fascia) which, like the triangular ligament or deep perineal fascia, is divisible into two layers. The deeper layer is the *fascia of Colles.* It is continuous, at the posterior border of the transversus perinei muscles, with the triangular ligament (Fig. 2283, No. 7). It passes superficial to the muscles and is attached firmly to the superficial lips of the pubo-ischiatic rami and the adjacent ischial tuberosities, but is *not attached* to the superficial lip of the subpubic arch, for the corpora cavernosa and the corpus spongiosum intervene (Fig. 2284, Nos. 1, 1). Colles' fascia, in this region, is continuous with the dartos of the scrotum (Fig. 2283, Nos. 7, 8).

This *superficial perineal cavity* is bounded thus on the pelvic side by the triangular ligament (Fig. 2283, No. 2), on the cutaneous side with the fascia of Colles (Nos. 7, 8), laterally by the intermediate surface of each pubo-ischiatic ramus (Fig. 2284, No. 4), and dorsally (posteriorly) by the line of junction of Colles' fascia and the triangular ligament (Fig. 2283, No. 7). The superficial perineal space is continuous ventrally with the *sub-dartos* space of the scrotum and penis (Fig 2283, No. 8; Fig. 2284, Nos. 1, 1).

It is in the superficial perineal cavity that extravasation of urine most frequently takes place in cases of rupture of the urethra. From the nature of the fascial attachments, it is clear that the only direction in which the fluid can make its way is ventrad along the scrotum and penis and thence on the ventral part of the abdomen.

This superficial perineal space contains the following *intraperineal* segments of the penis, viz.: the crura penis (Fig. 2284, No. 2; Fig. 2283) partly covered by the erector penis muscle, the bulb and part of the body of the corpus spongiosum (Fig. 2283, Nos. 1, 1, 1; Fig. 2284, No. 3) hidden by the accelerator urinæ muscle, the transversus perinei muscles, and the superficial perineal blood-vessels and nerves.

The crura penis (homologous with the crura clitoridis of the female) are the intraperineal and diverging parts of two fibrous cylindrical tubes called the corpora cavernosa. The latter are placed side by side and intimately connected by the septum pectiniforme along the median plane for their anterior (extraperineal) three-fourths (Figs. 2284 and 2285); the posterior (intraperineal) fourth of each corpus cavernosum diverges from its fellow to form a strong tapering fibrous process firmly connected to the pubo-ischiatic ramus. In many mammals (*e.g.*, lemurs and apes), a bone, the *os penis*, is developed in the septum between the corpora cavernosa.

The corpus spongiosum, a single, bilaterally symmetrical structure, is composed also of two parts, an intra- and an extraperineal portion.

The intraperineal portion commences between the diverging crura penis, where it forms an enlargement, the *bulb*, and then narrowing forms a part of the body (Fig. 2283, Nos. 1, 1, 1; Fig. 2284, No. 3). The extraperineal part is composed of two segments, the remaining portion of the body (Fig. 2283, No. 15) and the *glans penis* (No. 14). The body is cylindrical and situated in a groove on the ventral surface of the corpora cavernosa (Fig. 2285, No. 10). The glans penis overlaps the rounded extremities of the corpora cavernosa and presents the form of an obtuse cone flattened dorso-ventrally (Fig. 2283, No. 14). At its summit is a vertical opening, the meatus urinarius. The base forms a projecting rounded border (corona), behind which is a constriction (neck). Both these parts have numerous sebaceous glands secreting a cheesy matter of peculiar odor.

The three fibro-elastic tubes (viz., the corpus spongiosum and the corpora cavernosa) enclose a fibrous trabecular structure whose meshes lodge the erectile tissue. The trabeculæ are more delicate and the meshes smaller in the corpus spongiosum. The meshes or areolæ of the corpus spongiosum freely communicate with one another. The areolæ of the corpora cavernosa freely communicate with one another on each side, and also with those of the opposite side through fissures in the fibrous septum between them. The areolæ are lined with epithelial cells and are comparable to widely dilated capillaries. At several points in their walls arteries communicate with them; they give origin to the veins. Blood rushing into, and being retained in the, areolæ causes erection of the penis.

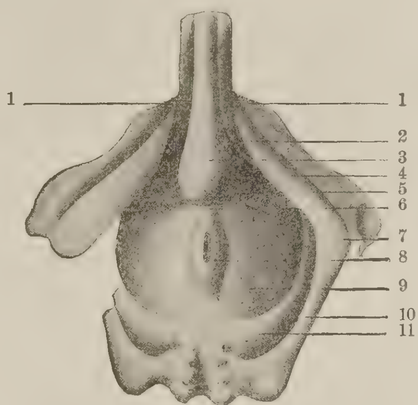

FIG. 2284.—Male Perineum, Showing Triangular Ligament and the Intra- and Extraperineal Portions of the Penis. Colles' fascia and the superjacent parts have been removed. 1, 1, Region of subpubic arch hidden by penis; 4, rami of pubes and ischium (pubo-ischiatic rami); 7, tuberosity of ischium (drawn much too far dorsad); 6, central tendon of the perineum, between which and the tuberosities of the ischium extend the transversus perinei muscles (omitted in the drawing); 5, triangular ligament or deep perineal fascia, on the superficial or perineal layer of which are shown the following structures, viz.: 3, the bulb of the corpus spongiosum from which the enveloping accelerator urinæ muscle has been removed; 2, crus penis of the corpus cavernosum, from which on either side the enveloping erector penis muscle has been removed. 8, Sphincter ani; 9, levator ani. The dorsal boundary of the triangular ligament is seen in the figure to extend as far back as the central tendon, where it is continuous with Colles' fascia. The triangular ligament is shown to be attached to the deep or pelvic lip of the pubo-ischiatic rami and subpubic arch; Colles' fascia has been removed from the superficial lip of the rami. The portions of the penis dorsad from the subpubic arch are intraperineal portions, while the parts ventrad of the arch are extraperineal.

The corpus spongiosum and the corpora cavernosa, with their envelopes, constitute the penis. The intraperineal segments of the penis converge at the apex (ventral part) of the superficial perineal cavity and, passing out of the cavity beneath the symphysis pubis (Figs. 2283 and 2284, Nos. 1, 1), form the pendulous body (extraperineal portion) of the penis. A strong band of fibrous tissue (the suspensory ligament of the penis) passes downward from the symphysis and blends with the fibrous cylinders of the corpora cavernosa (Fig. 2283).

The urethra (spongy portion) extends throughout the length of the corpus spongiosum and terminates at the meatus urinarius.

The erector penis muscle (homologous with the erector clitoridis) embraces the crus penis and arises from the intermediate space of the pubo-ischiatic ramus and the ischial tuberosity. It is inserted into the sides and ventral surface of the crus. By compressing the crus it assists in causing and maintaining erection. The accelerator urinæ muscle is bilaterally symmetrical. It is also called the ejaculator seminis. It is homologous with the sphincter vaginæ or bulbo-cavernosus of the female. It arises from the central tendinous point and from the median raphe in front. From these points its fibres diverge like the plumes of a feather. The greater number course around the sides and are inserted into the dorsum of the intraperineal part of the corpus spongiosum, while the foremost fibres extend around the lateral part of each corpus cavernosum and are inserted into the midline of the dorsum of the two bodies, covering the dorsal vessels. By compressing the latter it helps to cause and maintain erection. The superficial layer of the superficial perineal fascia acquires no bony attachments and is continuous with the corresponding fasciæ of the secrotum, thighs, and ischio-rectal fossæ.

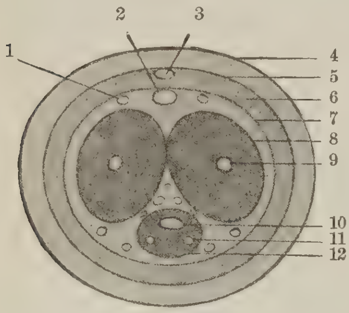

Fig. 2285.—Transverse Section of the Penis. Diagrammatic. 1, Dorsal artery; 2, deep dorsal vein; 3, superficial dorsal vein; 4, skin; 5, dartos (superficial layer of superficial fascia); 6, deep layer (areolar tissue) of the superficial fascia; 7, deep fascia; 8, cylindrical membrane containing erectile tissue of corpus cavernosum; 9, artery of corpus cavernosum; 10, spongy urethra in corpus spongiosum; 11, branch of artery of bulb supplying corpus cavernosum; 12, cylindrical membrane containing erectile tissue of corpus spongiosum; surrounding the latter are several blood-vessels.

The common envelopes of the extraperineal penis are the skin, superficial fascia (containing the dartos), and deep fascia. The dartos is the superficial layer of the superficial fascia and contains unstriped muscular fibres, and is continuous with the dartos of the scrotum. When contracted, it compresses the veins of the penis and favors erection. The skin is remarkably thin, is loosely connected with the deeper parts, is dark in color, and free from adipose tissue.

The erectile structures receive sympathetic nerves from the pelvic plexus and spinal nerves from the superficial perineal and the dorsal nerve of the penis. The coverings of the penis receive nerves from the inferior perineal of the internal pudic and from the genital branch of the genito-crural nerve. They receive *blood* from the external pubic artery, and from the superficial perineal and dorsal artery of the penis, branches of the internal pudic. The bulb and body of the corpus spongiosum are supplied by a branch (artery of the bulb) of the internal pudic. Each corpus cavernosum receives the cavernous branch of the internal pudic. The glans is mostly supplied by the dorsal artery of the penis (Fig. 2285).

The *veins* from the envelopes of the penis converge to the dorsum of the organ and empty into the superficial dorsal vein, lying in the areolar tissue beneath the dartos along the median line and emptying into the obturator and external pudic veins. The veins from the glans emerge at its neck and form the deep dorsal vein which runs in the median groove on the cavernous bodies beneath the deep fascia (Fig. 2285). It perforates the triangular ligament and empties into the prostatic plexus. Those from the body and bulb enter the same plexus or the internal pudic vein. Small veins emerge from the ventral and dorsal surfaces of the corpora cavernosa. They empty into the deep dorsal vein, the former circling around the sides of the bodies. The principal vein comes from the posterior part of each cavernous body, and, perforating the triangular ligament, enters the prostatic plexus.

The superficial lymphatics of the penis empty into the superficial inguinal glands, while the deep lymphatics empty into the pelvic glands about the internal iliac artery.

The Testicle, Spermatic Cord, and their Envelopes.—The testicle is the gland that secretes the male germ cells or spermatozoa (Figs. 2286 and 2287). It is supplied with arteries, veins, lymphatics, nerves, and an excretory duct (vas deferens). In migrating, during development, from the abdomen it evaginates a portion of the peritoneum (visceral and parietal layers, which subsequently become pinched off and form the *tunica vaginalis*) and all the layers of the abdominal wall in the inguinal region. It pushes in front of it, hernia-like, the following layers in addition to the peritoneum—viz., first, the *subperitoneal connective tissue,* and then, in order, the *infundibuliform fascia* (portion of transversalis fascia), some of the lower fibres of the internal oblique muscle thus forming the *cremasteric fascia,* the *intercolumnar fascia,* the *dartos* (superficial fascia rich in unstriped muscular fibres), and, finally, the *skin* (Fig. 2286). The path of the testicle through the abdominal wall is the *inguinal canal;* the evaginated, many-layered pouch is the *scrotal sac,* one on either side. By fusion the skin forms a common covering for both testicles, the line of fusion being indicated by the raphe; but the remaining layers meet in the median plane to form the *septum scroti.* All the envelopes of the two glands together form the *scrotum.* The deep "opening" of the inguinal canal is the *internal abdominal ring;* the superficial or subcutaneous end is the *external abdominal ring* (Fig. 2279, *Ext. Ab.*).

The inguinal canal is oblique and runs parallel with Poupart's ligament. It is about an inch and a half in length. It commences near the middle of Poupart's ligament and half an inch cephalad from it, and extends to the spine of the pubis. Its cephalic boundary is the arched fibres of the internal oblique and transversalis muscles; its caudal boundary is formed by the union of Poupart's ligament with the transversalis fascia; the ventral boundary is the skin, superficial fascia, aponeurosis of the external oblique, and partly by the internal oblique; the dorsal boundary is the triangular fascia, the conjoined tendon of the internal oblique and transversalis muscles, the subperitoneal connective tissue, and peritoneum.

The testicle, in migrating from the abdomen into the distal part of the scrotum, carries with it its tributary structures, such as the vas deferens, arteries, veins, lymphatics, and nerves, all bound together with connective tissue into a *spermatic cord* (Fig. 2287). The spermatic cord extends from the testicle to the internal abdominal ring, and is therefore divisible into a scrotal and an inguinal portion.

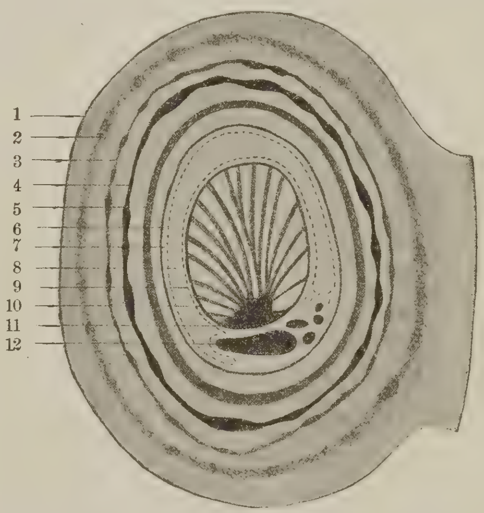

Fig. 2286.—Transverse Section of the Testicle and its Scrotum. Diagrammatic. For the sake of clearness the individual layers of the scrotum are represented as widely separated. 1, Skin; 2, dartos (superficial fascia); 3, intercolumnar fascia; 4, cremasteric fascia; 5, infundibuliform fascia; 6, subperitoneal fascia; 7, parietal layer of the tunica vaginalis; 8, cavity of the tunica vaginalis; 9, visceral layer of the tunica vaginalis connected by subserous areolar tissue to the tunica albuginea (10); 11, the mediastinum giving off trabeculæ to the tunica albuginea; 12, epididymis.

The Testicles. Each testicle consists of two separate but closely related parts, viz., the testicle proper, or didymis (Fig. 2287, *Tunica vag. Vis*), and an epididymis (*globus major, globus minor*). Each didymis is compressed laterally and is oval in form. It is one and a half

Genital Organs.

to two inches long (38 to 50 mm.), an inch and a quarter (30 mm.) dorso-ventrally, and one inch (25 mm.) in breadth. It weighs about six drachms (24 gm.). It has a lateral, convex surface looking outward and a little backward; a median, flat surface looking inward and a little forward. The dorsal border, nearly straight, is directed backward and upward and has attached upon its entire length, nearer its lateral than its median part, a structure composed of convoluted tubules and called the *epididymis.* The ventral border of the testicle looks forward and slightly downward. The inferior or caudal extremity is pointed and occupies a plane postero-internal to the more rounded upper or cephalic extremity. The epididymis consists of an enlarged cephalic *head* (*globus major*), a central portion or *body*, and a caudal, pointed *tail* (*globus minor*). The tubules of the globus major are continuous directly with those of the testicle (Fig. 2288, No. 3), but the body and globus minor are connected to the testicle by the tunica vaginalis and its subserous connective tissue. In horizontal section the body resembles a comma, and therefore it shows it to possess a ventral and dorsal surface, as well as lateral and median borders. The dorsal surface is convex, the ventral is concave. Between the concave surface and the testicle is a blind depression (*digital fossa*) opening laterally. The median border corresponds to the tail of the comma.

There are found connected with the globus major and neighboring part of the testicle two small bodies (*hydatids of Morgagni*), one of which is sessile and the other pedunculated (Fig. 2287). The former, one-eighth to one-third of an inch (3 to 8 mm.) in length, is flattened or rounded, and situated ventrally either on the globus major, the adjacent part of the testicle, or between the two; the latter, about the same size, is attached to the globus major. The hydatids are fœtal vestiges.

The testicle proper (didymis), as distinguished from its epididymis, is a fibro-glandular structure (Fig. 2288). The outermost part (*tunica albuginea*) is a dense connective-tissue membrane, which at the dorsal border is reflected ventrally into the gland and forms an incomplete vertical septum (*mediastinum*). From the sides and front of the mediastinum numerous connective-tissue cords and laminæ (*trabeculæ*) radiate to the inner surface of the tunica albuginea. Thus the interior of the gland is divided into a number (about two hundred) of incomplete cone-shaped spaces (*loculi*), which have their bases at the inner surface of the tunica albuginea and their apices at the mediastinum. In the cone-shaped loculi and lining the tunica albuginea and trabeculæ is a vascular layer (*tunica vasculosa*) consisting of a network of minute blood-vessels held together by delicate connective tissue. The true glandular tissue (seminiferous tubules) occupies the loculi. Each loculus contains two or three seminiferous tubules (*tubuli seminiferi*), commencing at the base of the space by blind extremities and taking a very convoluted course to the apex of the loculus. In their course toward the mediastinum they give off two or three blind pouches, and not only make anastomoses with one another, but also with the tubules in adjacent loculi. The tubules of each loculus, near its apex, unite together and form a single, straight, excretory tube (*tubulus rectus*) which enters the mediastinum. The tubules of a single loculus are bound together by a delicate interstitial connective tissue, rich in minute blood-vessels, and make a cone-shaped body (*lobule*) with the apex at the mediastinum. Each little tube in a lobule is about $\frac{1}{120}$ in. ($\frac{1}{5}$ mm.) in diameter, and when uncoiled its length is increased about thirty times (about 2 ft. or 62 cm.). The tubuli recti, formed as already described at the apices of the lobules, are smaller in diameter than the convoluted tubules of the lobules. They enter the mediastinum and form throughout that structure a network of anastomosing tubules (*rete testis*) of varying diameter, but always larger than the tubuli recti or convoluted tubules of a lobule. They have no proper wall, but are excavations in the mediastinum lined by epithelium of varying character. At the dorso-cephalic part of the testicle these channels finally unite to form about twelve tubes (*vasa efferentia*), which escape almost immediately through the tunica albuginea and enter into the globus major of the epididymis. The vasa efferentia, shortly after piercing the tunica albuginea, become greatly convoluted and form about twelve cone-shaped bodies (*coni vasculosi*) with their bases turned away from the tunica albuginea. They are each about one-third of an inch (or 8 mm.) long and enter a common duct and together constitute the globus major. This common duct extends downward, as the *tube of the epididymis*, and, greatly convoluted, forms the body and globus minor. The coils are held together by connective tissue. The length of the tube when uncoiled is about 15 ft., or 4.5 metres. Its diameter above is about $\frac{1}{60}$ in., or $\frac{2}{5}$ mm., but gradually decreases toward the globus minor and then enlarges beyond that structure. The tube consists of an inner mucous coat lined with ciliated columnar cells, and an outer coat of unstriped muscular fibres. The tube of the epididymis emerges from the globus minor as a constituent (*vas deferens*) of the spermatic cord (Figs. 2279 and 2288).

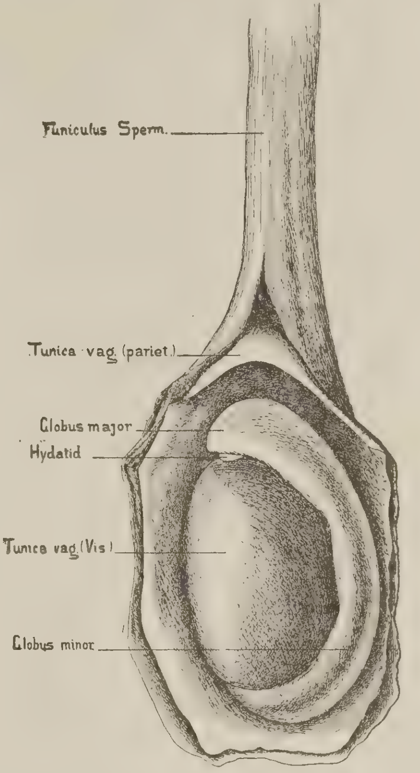

FIG. 2287.—Lateral Surface of the Left Testicle. (Modified from Gegenbaur.) All the layers of the scrotum down to and including the parietal layer of the tunica vaginalis, cut through and turned aside, thus exposing the cavity and the visceral layer of the tunica vaginalis; the latter enveloping the didymis (*Tunica vag. Vis.*), the epididymis (*Globus major*, *Globus minor*), and the hydatid.

Spermatogenesis.—The male germ cells are formed only in the convoluted tubes of the lobules of the testis. The process is homologous with oögenesis (maturation of the ovum) in the female. If a section of a seminiferous tubule be examined, the following arrangement will be observed: Each tubule presents several layers of cells. The layer furthest from the lumen of the tube is formed principally by a number of cells called *spermatogones.* Each of these, from time to time, divides into two daughter cells, one of which persists as a spermatogone, while the other differentiates into a *primary spermatocyte,* thus forming a layer nearer the lumen. This latter cell divides into two cells, the *secondary spermatocytes,* thus forming a layer still nearer the lumen. These undergoing division present a layer of *spermatids*, each one of which develops into a *spermatozoon*. In addition to the preceding cells there are others, found in all the layers, which serve the purposes of supporting and nourishing cells (Sertoli cells). The spermatozoa form the layer of cells next to the lumen. Each spermatid, in differentiating into a spermatozoon, gradually elongates; its nucleus becomes the head of the spermatozoon enveloped by a very thin film of protoplasm; the centrosome lies behind the nucleus in the middle piece or neck; the tail develops behind the neck; an axial filament runs through the neck and tail extending beyond the sheath of the latter as the end-piece. The head is from 2 to 3 μ in breadth and from 3 to 5 μ in length; the neck is 6 μ long and 1 μ ($\frac{1}{25000}$ inch) in breadth; the tail is from 40 to 60 μ long; the end-piece is 6 μ long. In profile view the head is narrow and pointed at its free end, but on surface view it appears oval in shape.

The rate of progression of a spermatozoon is about 0.05 mm. per second.

Spermatozoa possess remarkable vitality. When mounted on a slide and protected from evaporation they have exhibited motility for nine days. They have been found alive in the male genital tract four days after death. They may retain their activity in the female genital tract for several weeks.

Weak acid solutions kill them.

Structure of the Spermatic Cord. The *vas deferens* forms the axis of the cord and is about eighteen inches (46 cm.) in length. It is in the dorsal part of the cord and is recognizable from its cord-like resistance to pressure.

The *spermatic artery* is ventral to the vas, and near the testicle becomes tortuous and divides into several branches, two or three of which accompany the vas and supply the epididymis; others pierce the tunica albuginea and supply the testicle proper (*didymis*). The *deferential artery* is a long, slender vessel accompanying and supplying the vas on its dorsal side and anastomosing with the spermatic near the testis. The *cremasteric artery* courses along the cord supplying the cremasteric and other coverings. Seven or eight *spermatic veins* emerge from the dorsal surface of the testis median to the epididymis, and unite to form the *pampiniform plexus* passing mostly along the ventral plane of the vas and constituting the bulk of the cord. Farther up the cord they are reduced to two or three in number; at the internal abdominal ring they have united into one or two spermatic veins. *Lymphatic vessels* accompany the veins. Plexuses of *sympathetic nerves* accompany the arteries.

Except for a short distance above the testicle, the scrotal portion of the spermatic cord is lacking in the serous envelope; otherwise the coverings are identical with those of the testis. The inguinal part of the cord has only the following coverings, viz., the subserous connective tissue, the infundibuliform fascia, and cremasteric fascia.

At the internal abdominal ring the constituents of the spermatic cord separate and course in different directions. The vas deferens, after winding around the outer side of the deep epigastric artery, and crossing the external iliac vessels, descends at the side of the bladder into the pelvis. It arches downward and backward to its base, crossing the vestigial hypogastric artery to reach the median side of the ureter. At this point it is sacculated and enlarged, forming the *ampulla*, which extends to the base of the prostate gland (Fig. 2283, No. 3). The ampullæ are median from the vesiculæ seminales, and are between the bladder and the second part of the rectum. They constitute the lateral boundaries of the external trigone of the bladder. At the base of the prostate gland the vas deferens becomes narrowed and, uniting here with the duct from the seminal bladder, forms the *ejaculatory duct* (Fig. 2283). The vas deferens is about two feet (61 cm.) in length and about a line and a quarter (3 mm.) in diameter. The spermatic artery can be traced crossing obliquely the external iliac artery and ureter to the aorta a little below the renal artery. It rests on the psoas magnus muscle behind the peritoneum. The right one passes across the inferior vena cava.

On either side two spermatic veins generally accompany each spermatic artery for a distance and then fuse into a single vein. The right one opens obliquely into the inferior vena cava, the left one into the left renal vein at a right angle. The left spermatic veins pass behind the sigmoid colon with their artery. The deferential artery can be traced to the superior vesical artery at the side of the bladder. The cremasteric is a branch of the deep epigastric artery. The lymphatic vessels terminate in the lumbar glands. The sympathetic nerves are the spermatic plexus derived mostly from the renal, but partly from the aortic plexus. The plexus is re-enforced through the deferential from the pelvic plexus.

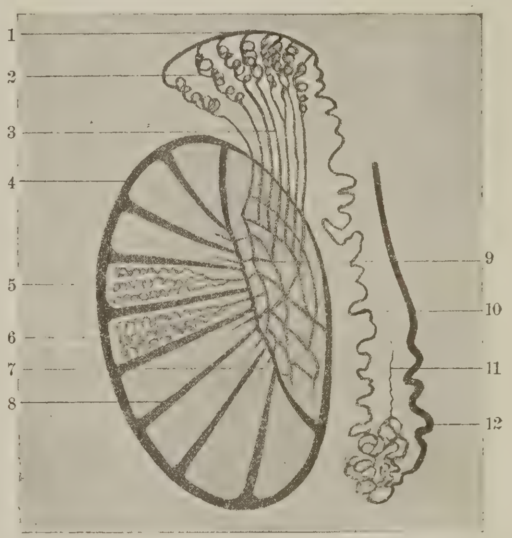

FIG. 2288.—Diagram of testicular tubules. 1, Collecting tube of the epididymis; 2, coni vasculosi; 3, vasa efferentia; 1, 2, and 3 form the globus major; 4, tunica albuginea; 5, loculus containing a lobule; 6, lobule; 7, one of the vasa recta; 8, trabecula; 9, rete testis in the mediastinum; 10, tube of the epididymis forming the body and globus minor; 11, vas aberrans; 12, vas deferens.

Dorsal to the spermatic cord is the internal branch of the genito-crural nerve from the lumbar plexus. It innervates the cremaster muscle. The ilio-inguinal nerve from the lumbar plexus enters the inguinal canal at varying points and appears at the external abdominal ring ventral to the cord. It gives sensibility to the scrotum.

Tunica Vaginalis (Fig. 2287). As already stated, the tunica vaginalis is the innermost of the scrotal coats of the testis, derived from the peritoneum during the descent of the testis. At birth the cavity of the tunica is directly continuous with that of the peritoneum, so that the tunica consists of inguinal, scrotal, and testicular segments. But, usually, a short time after birth, the inguinal and upper scrotal parts are reduced to a fibrocellular thread lying in the loose connective tissue around the spermatic cord; so that the tunica vaginalis is reduced to a testicular portion. There are all grades of variation between a tunica vaginalis whose cavity is freely continuous with the cavity of the abdominal peritoneum and one whose cavity is absolutely shut off from that of the abdomen, and without even the presence of a vestigial connective-tissue thread.

The *visceral layer* of the tunica is closely adherent to the testicle proper, and to the globus major and lateral part of the body of the epididymis, and is prolonged upward upon the spermatic cord for half an inch (12 mm.). It extends into the digital fossa between the epididymis and testicle. It leaves uncovered nearly all the postero-internal part of the body and the globus minor of the epididymis. It is in those uncovered parts that extensive vascular communication is established between the testicle and its coverings and the cord. The *parietal layer* is continuous with the visceral layer at the point of reflection from the spermatic cord, and at the postero-inferior parts of the testicle. It is loosely connected with the infundibuliform fascia by the subserous connective tissue. The two layers are in contact normally except for a very thin film of serous fluid secreted by the endothelial cells of the tunica.

The Seminal Vesicles (Fig. 2283, No. 4). These reservoirs for the semen, to which they add their own secretion, are situated between the bladder and the rectum. They are lobulated pouches of pyramidal shape placed one on either side external to the ampullæ of the vasa deferentia, and are two inches (50 mm.) long and a half-inch (12 mm.) wide at the base. They present rectal and bladder surfaces, median and lateral borders, a base and an apex. The ventral surface is attached to the base of the bladder overlapping the ureter. The rectal surface is covered above by the recto-vesical pouch of the peritoneum, but below is separated from the rectum only by the recto-vesical fascia. The bases are widely separated, but the apices converge and narrowing into straight ducts unite, near the base of the prostate gland, with the corresponding vasa deferentia to form the ejaculatory ducts.

Each vesicle consists of a single tube coiled upon itself and giving off many blind diverticula, all bound together firmly by fibrous tissue. When uncoiled the main tube is about five inches (125 mm.) in length and of the diameter of a quill.

Each ejaculatory duct is about three-quarters of an inch (19 mm.) long, and commencing at the base of the prostate it runs downward and forward between the lateral and middle lobes to empty into the urethra, near or through the uterus masculinus. The seminal vesicles and ejaculatory ducts have three coats: an inner or mucous one, a middle or muscular one, and an outer or areolar one.

The nerves of the vesicles and ducts are derived from the pelvic plexus. The middle hemorrhoidal and the vesical arteries supply the vesicles and the extraprostatic portion of the duct. The intraprostatic portion receives its nutriment from the prostatic vessels. Veins and lymphatics accompany the arteries, emptying into the vesico-prostatic plexus.

Prostate Gland (Fig. 2283, No. 3). The prostate is a musculo-glandular body surrounding the proximal urethra and the neck of the bladder. It is in the pelvic cavity behind the lower part of the symphysis pubis. It is cephalad from the deep layer of the triangular ligament of the urethra (deep perineal fascia). It is about the shape and size of a large chestnut. It develops at puberty and atrophies after castration. It presents a base, an apex, a ventral, a dorsal, and two lateral surfaces. The base is situated immediately below the bladder; the apex rests upon the pelvic side of the triangular ligament; the dorsal surface rests on the rectum, distant about one inch and a half (37 mm.) from the anus; the ventral surface, about three-quarters of an inch (19 mm.) behind the symphysis, has some loose fat and a plexus of veins in front of it, and is connected on either side to the pubic bone by the pubo-prostatic ligaments; the lateral surfaces are in relation with the anterior portions of the levator ani muscles, the vesico-prostatic plexus of veins intervening. The prostate consists of a median and two lateral lobes. The lateral lobes are separated by a deep notch at the base and by a slight furrow on the ventral and dorsal surfaces. The middle lobe, variable in shape, is a small transverse band, placed between the two lobes at the posterior part of the gland, behind the proximal urethra. The ejaculatory ducts pass between the middle and lateral lobes. The prostate is enveloped by a thin but firm fibrous capsule continuous with the pelvic layer of the triangular ligament and the recto-vesical fascia. It consists of stroma (mostly muscular) and glandular tissue. Immediately beneath the fibrous capsule is a thick muscular layer, and around the prostatic urethra is another strong, circular, muscular layer; extending between the two are a series of decussating muscular trabeculæ, forming interstices that contain the glandular tissue. The tubular glands are arranged around the urethra in a radiating manner, and their ducts (about thirty in number) communicate by minute orifices with the prostatic sinus on either side. They are lined with columnar epithelium and secrete a milky fluid, which is added to the seminal fluid at the moment of ejaculation.

The prostate is supplied by the internal pudic, vesical, and hemorrhoidal arteries. The veins empty into the vesico-prostatic plexus surrounding the organ, and thence into the internal iliac vein. The nerves are derived from the pelvic plexus.

Cowper's Glands. These glands are two firm lobulated bodies about the size of peas and situated, one on either side of the membranous urethra, between the two layers of the triangular ligament (Fig. 2283, No. 2). They lie close above the bulb among the fibres of the compressor urethræ muscle. Each body is a compound racemose gland, and its duct, lined by columnar epithelium, pierces the perineal layer of the triangular ligament and runs forward for about an inch (25 mm.) under the mucous membrane, finally emptying into the spongy urethra. The viscid, albuminoid, transparent secretion of these glands is mixed with the seminal fluid at the moment of ejaculation.

Daniel Kerfoot Shute.

GENTIAN.—Gentiana. "The dried rhizome and root of *Gentiana lutea* L. (fam. *Gentianaceæ*)," U. S. P. This, the yellow gentian, is one of the largest and showiest species of the genus. It is a tall, sturdy, mountain perennial, arising from a thick, fleshy, slightly branching or simple, and sometimes very long (from half a metre to one metre or more), yellowish-brown root, and is a yard or more high. It grows abundantly in the elevated and mountainous parts of Southern and Middle Europe, Asia Minor, etc. In Switzerland, Southern France, and the hilly parts of Germany, it is collected for use. Although sometimes cultivated for ornament, it does not thrive well, and rarely flowers except in its native pastures.

Description.—In cylindraceous, usually slightly flattened, curved or crooked pieces of indefinite length, and from 0.5 to 3.5 cm. (¼ to nearly 1½ in.) thick, or in longitudinal slices of the same thickness; externally yellowish-brown to dark brown, strongly and crookedly longitudinally wrinkled, and marked with lighter-colored circular root scars, the rhizome finely or heavily annulate; somewhat tough and flexible when damp, rather brittle when dry, the fracture short but uneven, the bark thick, reddish-brown, separated by a dark brown line from the yellowish or reddish-yellow inner portion; free from starch; odor strong, characteristic; taste very bitter, slightly sweetish. The roots of other species are distinguished by their smaller size and tendency to divide into numerous branches at the top. Their introduction is to be regarded as only technically an adulteration, as their properties are identical with those of the official root.

Composition.—The principal constituent of this and other gentians is the peculiar, intensely bitter, crystalline glucoside, *gentiopicrin*, first obtained in a state of purity in 1868, by Kromeyer, from fresh gentian root. It cannot, so it is said, be made to crystallize from that which has been dried. It forms clear, radiate, or clustered needles; is soluble in water and diluted alcohol, but not in ether; and by means of diluted acids it is separated into sugar and *gentiogenin*, a yellow, bitter, neutral powder. The yield is about one and two-thirds *per mille*. *Gentisic acid* is more abundant. It is in large needle-shaped crystals, tasteless, and almost insoluble in water and ether, but slightly soluble in alcohol. It is not an active substance. The root also contains a good deal of pectic matters, sugar (gentianose), etc., but no starch, and probably no tannic acid, unless the gentisic acid be considered a form of tannin.

Action and Use.—Gentian is the most perfect type at our command of the class of medicines called "simple bitters." In the purity of its bitter taste, the promptness of its action upon the assimilating organs, and the absence of other qualities even in considerably larger than medicinal doses, it has no equal. Concerning its physiological action in a definite way—that is, as shown by experiments in laboratories—we know but little, the more striking effects of active poisons having greater fascination for physiologists. *Gentisic acid*, when taken even to the extent of several grams, has no special action. *Gentiopicrin* has not been tested, to the writer's knowledge, in a pure state; but the older *gentianins*, etc., consisting of mixtures of the above two substances, have never shown themselves poisonous. In excessive quantities gentian and its preparations disturb the stomach and bowels, and may occasion nausea and vomiting. Sometimes it appears to be slightly laxative. Gentian is employed in medicine almost exclusively for the purpose of obtaining its stimulating effect upon the appetite, gastric secretion, and assimilating functions. Under its influence the appetite improves, the feeling of weight or discomfort felt in the stomach or bowels after eating—if due to debility of those organs—disappears, more food is taken, and probably more of what is taken is assimilated. It must be borne in mind that it probably, like other bitters, has a slight inhibitory action upon the digestive process by its presence in the mass of food. The secondary effect—viz., the improved nutrition of all the organs, and their consequently better performance of their various functions—is what is known as a tonic effect. Strength, weight, color, firmness of tissue, are all improved, and better health results. This drug is, then, indicated in debility, with poor appetite, of a more or less chronic character. Of course, acute and sudden depression, such as collapse or shock, or the weakness of fevers during the stage of high temperatures, are to be treated by stimulants, and are not suitable ones for tonics alone; but, on the other hand, during the recovery from all severe illnesses gentian may be of great value. It is often of service in dyspepsia, and, in combination with iron, in simple anæmia. As an antiperiodic it has been completely superseded by quinine; as a substitute for tobacco and opium in the treatment of those habits it has no special value.

ADMINISTRATION.—Gentian, in the form of the whole root, is sometimes chewed, and the salivary extract swallowed; the method, although troublesome, is an excellent one. The dose is not particularly important, but 2 or 3 gm. will probably do as much good as a larger quantity. There are several widely used preparations, all good. The extract (*Extractum Gentianæ*, U. S. P.), an infusion evaporated to a pillular consistence, is a nearly black, pleasant-smelling, but very bitter, soft solid, scarcely firm enough to make permanent pills. Dose, a gram or less. The fluid extract (*Extractum Gentianæ Fluidum*, U. S. P.), made with diluted alcohol, is less used than the other preparations, but represents the root well. The compound infusion (*Infusum Gentianæ Compositum*, B. P.), although not now officinal here, is considerably used; its strength is 12.5 gm. to 1,000 c.c. with orange and lemon peel. Dose, a wineglassful or two. But the most commonly used of all, and probably the most perfect bitter tonic ever made, is the compound tincture (*Tinctura Gentianæ Composita*, U. S. P.), which has the following composition: Gentian, 10 parts; bitter orange peel, 4 parts; cardamom, 1 part; percolated with diluted alcohol until 100 parts of tincture are obtained. The addition of aromatics in the last two preparations greatly enhances their value. *W. P. Bolles.*

GENTIANACEÆ.—(*The Gentian Family.*) The great size and wide distribution of this family, and the singular uniformity of its species in agreeing with the general composition and properties of the drug last discussed, render it of great importance that army surgeons and travellers generally should be able to recognize them when seen. There are no poisonous plants among them. A very few are slightly or not at all bitter and their roots or leaves are edible. Several *Coutoubeas* are used as anthelmintics. With these exceptions, all the others in use, to the number of a hundred or more, have the properties of the official *Gentian* and *Chiretta.* Among these are a large number in the genera *Gentiana, Swertia, Lisianthus, Pleurogyne, Erythræa* (the "Centaurys"), *Sabattia, Axacum*, etc. All show a distinct tendency toward laxative properties, and in some this tendency is marked. The family contains upward of sixty genera and nearly a thousand species, Gentiana being the largest genus, with about three hundred species. The family is represented mostly in the temperate zones and in tropical mountains with a temperate climate. They may be known by the following family characteristics: They are mostly herbs, smooth, with opposite, entire, extipulate leaves, these usually nerved or ribbed. The flowers are solitary or cymose in the axils, or at the summit, the cymes often panicled. The flowers are regular, rarely a little oblique, perfect, 4–5-merous, the corolla gamopetalous. The stamens are of the same number as the corolla lobes, alternate with them and affixed to the corolla tube or throat. The disc, if any, is inconspicuous. The ovary is superior, one-celled, or rarely two-celled by the union of the two parietal placentæ. The ovules are numerous, anatropous or amphitropous. The fruit is usually a two-valved, dehiscent capsule, rarely indehiscent, still more rarely fleshy. The embryo is small, in copious albumen, the radicle, if its direction is distinct, ascending.

Henry H. Rusby.

GEOFORM, or gaiaform, prepared by the action of formaldehyde on guaiacol, is a yellow, non-irritant powder, without odor or taste. It is soluble in alcohol, ether, hot benzol, and solutions of soda or potassa, and is insoluble in water, petroleum ether, and benzin. Heated for several days it acquires an odor of vanilla. Used by Brissonet and others, it is claimed to be non-toxic, as much as 15 gm. (℥ ss.) a day having been administered, without inconvenience, to a dog weighing 16 kgm. (35 pounds). It is given in capsule in tuberculosis, the dose being that of guaiacol.

Tanno-geoform, its compound with tannin, is preferred for intestinal tuberculosis and night sweats, and for other sweating processes, such as hyperidrosis.

W. A. Bastedo.

GERANIUM.—CRANESBILL. *Wild Geranium.* "The dried rhizome of *Geranium maculatum* L. (fam. *Geraniaceæ*)," U. S. P. This plant is exceedingly abundant in woodlands about New York, and elsewhere in eastern and central North America, and is represented farther west by other species, with similar properties. It is a perennial slender herb, a foot or two high, with palmately lobed, roundish leaves, from two to six inches in diameter, and numerous lilac-purple flowers, something over an inch in breadth. The rhizome is of horizontal growth, 5 to 10 cm. (2 to 4 in.) long and 0.5 to 1.5 cm. ($\frac{1}{5}$ to $\frac{3}{5}$ in.) thick, more or less crooked, cylindraceous but somewhat vertically flattened, brown; roughly and shortly wrinkled and strongly, rather sharply tuberculate; fracture short, purple, the bark thin, a few short and broad yellowish wood-wedges scattered near the dark cambium; inodorous; taste strongly astringent.

Besides inert *mucilage, resin, coloring matters*, etc., geranium contains from ten to twenty-five per cent. or more of tannin, to which its medicinal value is owing. It is a mild, rather pleasant, vegetable astringent, and considerably employed in diarrhœa, chronic dysentery, etc., and as a wash, gargle, or injection, in catarrhs of the pharynx, vagina, or urethra. A fluid extract is official and represents it well for internal use. Dose, 1 to 2 c.c. (♏ xv. ad xxx.). For washes and gargles a ten-per-cent. decoction may be made in the usual way. Cranesbill is often selected, when an astringent is needed for a child, on account of its comparatively easy administration.

Geranium will probably be dropped from the next edition of the Pharmacopœia. *Henry H. Rusby.*

GERMANDER. See *Labiatæ.*

GERMAN MEASLES. See *Roetheln.*

GERMICIDES.—Modern science having established the fact that certain infectious diseases of man and of the lower animals are due to minute micro-organisms, popularly spoken of as "germs," the term *germicides* has been introduced to designate those agents which have the power of destroying the vital activity of such organisms.

Strictly speaking, a germ is the primitive reproductive element of an animal or vegetable organism. But medical authors, in advance of exact knowledge, have long been in the habit of speaking of the "germs of disease"; and since it has been shown that in certain instances these disease germs are minute vegetable organisms, belonging to the *bacteria,* a more definite idea is attached to the word germ, and the term germicide is understood as referring to an agent which has the power to destroy organisms of this class—micrococci, bacilli, and spirilla.

It is evident that an exact knowledge of the germicidal power of various substances is desirable with a view to therapeutic possibilities, and especially with reference to the destruction of disease germs external to the bodies of infected individuals—*disinfection.* As methods have been perfected by which organisms of this class—pathogenic or non-pathogenic—may be isolated and cultivated through successive generations in sterilized media—"pure cultures"—it has become possible to determine in an exact manner the germicidal power of a given agent as regards a particular germ; and in a general way to classify chemical agents with reference to their power to destroy bacterial organisms. Already much work has been done in this direction, and it is the object of the present article to place upon record the results of the determinations which have been made up to the present date.

But before referring in detail to the experimental data, it will be desirable to give an account of the methods of research, and to call attention to the various circumstances which influence the result, and which must be taken into consideration if we attempt to compare the data obtained by different experimenters.

In the case of pathogenic organisms *two methods of determination* are available: (*a*) the inoculation of germs which have been exposed to the action of a supposed germicide into a susceptible animal; (*b*) the attempt to cultivate germs exposed in the same way in suitable culture media. In the one case failure to multiply in the body of the test animal, and in the other failure to multiply under favorable conditions in a culture medium is taken as evidence of the germicidal power of the agent tested.

Extended experiments by the method of inoculation have been made upon the anthrax bacillus (Davaine, Koch), upon the tubercle bacillus (Schill and Fischer), and upon the micrococcus of rabbit septicæmia (Davaine, Sternberg). Experiments have also been made upon the virus of glanders (Reynal, Peuch, Vallin), upon that of symptomatic anthrax (Arloing, Cornevin, and Thomas), and upon the micrococcus of fowl cholera (Salmon).

This method is very definite and satisfactory so far as the negative results are concerned—that is to say, when the agent under trial fails to exercise any germicidal power. In this case the death of the test animal, and the fact that the pathogenic organism to which this result is due is found in its blood or tissues, is sufficient evidence of the failure of the agent under trial to destroy the vitality of the germ. But the survival of the test animal cannot be taken as positive proof that the agent to the action of which the test organism was submitted has completely destroyed the vitality of this organism. This for two reasons: *first,* the inoculated animal may suffer from a modified and non-fatal attack of the infectious disease, the germ of which is used in the test; *second,* in the case of a chemical agent which has been mixed in a given amount with a pure culture of the test organism, or with blood from an infected animal containing this organism, the agent is necessarily injected into the test animal along with the germs which have been subjected to its action, and may exercise a restraining influence upon the development of these germs without destroying their vitality. This would give time for their destruction in the body of the animal by those means which have been provided by nature. The writer has elsewhere suggested that this is probably one of the functions of the white blood corpuscles, and that, when the developing power of pathogenic organisms is restrained in any way, before or after their introduction into the body of a susceptible animal, this provision of nature may suffice to prevent an attack of the disease, or at least to modify its severity.

The *second method* permits of a more accurate determination when the experiments are conducted with a due regard to the possible restraining influence of the germicide agent, which by preventing growth might lead to the mistaken inference that the vitality of the test organisms had been destroyed. This error is to be avoided by diluting the germicide agent so largely with the sterilized culture fluid into which it is introduced, along with the test organisms which have been exposed to its action, that its restraining influence is rendered *nil.* Suppose, for example, that we mix with a culture of the anthrax bacillus containing spores an equal quantity of a solution of mercuric chloride of the strength of 1 to 1,000, making the proportion of the salt in the mixture 1 to 2,000. Now, if we take one part of this mixture and add it to ten parts of sterilized *bouillon,* we shall have the mercuric chloride present in the proportion of 1 to 20,000. Experiments upon the restraining power of this salt show that anthrax spores will not grow in culture solutions containing 1 to 300,000, and that their development is retarded by solutions of 1 to 600,000. Failure to develop in this case would therefore be no proof that the growing power of the anthrax spores had been destroyed. This proof is only to be attained by adding sufficient culture fluid to dilute the mercuric chloride beyond its restraining power. The use of a comparatively large amount of the culture fluid, and of an extremely small quantity of the material containing the test organisms, permits us to exclude this source of error, for a few germs serve as well for the test as a large number. Or we may wash the test organisms in a solution which has no germicidal action but which is capable of neutralizing chemically the agent which is being tested as to its germicidal power—*e.g.*, a solution of ammonium sulphide for corrosive sublimate.

For the reason stated fluid culture media are more suitable for experiments of this nature than solids. If we bring a little of our material containing mercuric chloride in the proportion of 1 to 2,000 upon the surface of a cooked potato, or introduce it with a needle into a gelatin culture medium, the salt will not be diluted, and would exercise its restraining influence upon the germs if they had not already been destroyed by its action. On the other hand, if we add 1 part of the material to 100 parts of *bouillon* and mix thoroughly by shaking, the mercuric chloride will be diluted to 1 to 200,000; this being still within the limits of its restraining action, we may take one part of the mixture and add it to 10 parts of the sterile *bouillon.* The mercuric chloride will now be diluted to 1 to 2,000,000, a proportion quite beyond the limits of restraining action. But there will be a sufficient number of anthrax spores in the culture medium to test the question as to whether the growing power of these particular "germs" is destroyed by mercuric chloride in the proportion named.

This source of error has not been kept sufficiently in view in some of the experiments heretofore made. Again, it often happens that no development occurs for a time, but that after several days the germs which have been exposed to the action of a chemical agent commence to grow, and finally produce an abundant and vigorous progeny. In this case mistakes are likely to arise from terminating the experiment too soon. Anthrax spores, for example, develop, in a suitable culture medium, at a temperature of 80° to 100° F., within twenty-four hours, and give rise to numerous characteristic flocculi, made up of long filaments, which are readily distinguished by the naked eye. But after exposure to a germicide agent in less amount than is necessary completely to destroy their vitality, they may fail to develop under the same circumstances in forty-eight or seventy-two hours, and yet finally produce an abundant crop of filaments.

Bearing in mind these sources of error, the germicidal value of a given agent may be determined approximately by a series of experiments, in which the quantity of the agent under trial is increased or diminished according as it fails or is successful in destroying the vitality of the test organism. But the data obtained by experiments upon a single organism can be applied only in a general way to others of the same class, for experiments which have been made show that within certain limits there are manifest differences in resisting power, and especially that there is a wide difference in this regard between organisms in active growth—micrococci, spirilla, or bacilli—and the reproductive bodies, called spores, which are developed in the interior of the bacilli at a certain period in their life history.

It will be seen from what has been said, that the germicidal power of a chemical agent can be stated in a definite manner only when reference is made to a particular germ. It is also necessary to take into account certain circumstances relating to the test organism and the medium in which it is placed, and, especially, to consider *the time* during which this has been exposed to the action of the germicide. Thus we may, by our experiments, determine how long a time will be required for the destruction of a given germ by means of a standard solution of a certain chemical agent. Or, on the other hand, we may determine the proportion in which this agent must be used in order to be effective in a given time. In Dr. Koch's elaborate experiments, published in the first volume of the "Mittheilungen aus dem Kaiserlichen Gesundheitsamte," the time is made the variable quantity. In the writer's numerous experiments a standard time was adopted—two hours in the more recent experiments—and the object in view was to determine the minimum quantity of the agent under trial which is effective in this time.

Evidently, a comparison of the results reported by different experimenters requires a consideration of this essential condition. But in addition to this we must consider the following circumstances:

(*a*) The presence or absence of spores.

(*b*) The physical condition of the test organism—whether it is dry or moist, whether suspended in fluid or embedded in masses of albuminous material, etc.

(*c*) The chemical properties and mode of action of the agent which is being tested.

(*d*) The temperature at the time the experiment is made. As a general rule the higher the temperature the more promptly the germicidal action of a chemical agent is manifested.

(*a*) As already remarked, spores are far more resistant than bacteria in active growth. Thus the spores of the anthrax bacillus require for their destruction a boiling temperature, while the bacillus itself is quickly destroyed by a temperature of 140° F. The same spores are not destroyed by being immersed for one month in a five-per-cent. solution of chloride of zinc, or for three months in absolute alcohol, or one hundred and ten days in a five-per-cent. solution of carbolic acid in oil; the last-mentioned solution, however, destroys the bacilli, in the absence of spores, in six days (Koch).

(*b*) The germicidal power of formaldehyd, sulphur dioxide, and of other gases is largely influenced by the physical condition of the test organisms—as to whether they are dry or moist, whether they are exposed in masses or in thin films, etc. And the same circumstances influence the result, to a less extent, in experiments with aqueous solutions of various agents. This is especially true as regards those agents which enter into combination with albuminous material; thus Schill and Fischer found that the tubercle bacillus was not destroyed in tuberculous sputum exposed for twenty-four hours to the action of mercuric chloride in solution in the proportion of 1 to 2,000, while dried sputum exposed to a solution of 1 to 5,000 failed to produce tuberculosis when inoculated into guinea-pigs. The difference was no doubt due to the fact that in the moist sputum the bacilli in the interior of the mass were protected from the action of the germicide agent. The result is also largely influenced in certain cases by the amount of non-living organic material associated with the germs to be destroyed. This is especially true as regards the oxidizing disinfectants. If, for example, we subject a given quantity of germs suspended in pure water to the action of potassium permanganate or of hypochlorite of lime, these agents will be effective in dilute solutions. But if the germs are suspended in a rich culture medium, or embedded in masses of organic material, this material will be quickly oxidized, and in the chemical reaction which occurs an amount of the reagent will be decomposed corresponding with the amount of organic material present in the solution; and only the excess of the oxidizing agent will be available for the destruction of such germs as may have escaped immediate destruction by reason of their resisting power, or because they were protected by being embedded in masses of material.

It will be desirable to extend the experimental researches in this direction as new pathogenic organisms are discovered, and to determine in an exact manner the value of each agent which has been shown to possess germicidal power for each organism of this class. In many of the experiments which have been made test organisms have been used which are known to be non-pathogenic, but which, belonging to the same class, give valuable data for the determination in a general way of the comparative germicidal value of various chemical agents. Thus, in many of the writer's experiments the bacteria of putrefaction, as found in "broken-down" beef-tea freely exposed to the air, have served as the test. As a variety of bacterial organisms are present in such material, including one or more species of spore-bearing bacilli, this serves as a general test, and there is reason to believe that all known pathogenic organisms would be destroyed by an agent capable of destroying all germs found in such material. These experiments, therefore, furnish reliable data upon which to base practical measures of disinfection. In practice it will be best to select such agents as stand the most rigid tests, and to use them in amounts somewhat in excess of what is shown by such tests to be necessary. (See article on *Disinfectants.*)

For convenience of reference we have arranged the following summary of the experimental data in alphabetical order:

Acetone.—Anthrax spores grow freely after two days' exposure to the action of this agent; after five days the development is feeble (Koch).

Acetic Acid.—A five-per-cent. solution did not prevent the development of anthrax spores after five days' exposure (Koch). In experiments made by Abbott, glacial acetic acid in the proportion of fifty per cent. failed to destroy anthrax spores in two hours, but twenty per cent. was effective with the spores of *B. subtilis,* and with the mixed organisms in broken-down beef-tea; and micrococci were destroyed in the same time by a one-per-cent. solution.

Alcohol.—In the writer's experiments it was found that ninety-five-per-cent. alcohol did not destroy the vitality of the organisms in broken-down beef-tea in forty-eight hours. The micrococcus of pneumonia was destroyed by two hours' exposure to a twenty-four-per-cent. solution. A micrococcus obtained from gonorrhœal pus required a forty-per-cent. solution. Koch found that absolute alcohol had no effect upon the vitality of anthrax spores which were immersed in it for one hundred and ten days. When saturated with camphor, alcohol does not destroy the virus of symptomatic anthrax (Arloing, Cornevin, and Thomas). In the proportion of 1 to 1.5 it destroys the bacteria which cause the acid fermentation of milk (Molke). Schill and Fischer found that when tuberculous sputum was mixed with an equal quantity of absolute alcohol, its infecting power was not destroyed (in twenty-four hours), but that, in the proportion of 5 parts to 1 of sputum, this agent was effective in destroying the tubercle bacillus, as proved by inoculation experiments.

Yersin reports that the tubercle bacillus in pure cultures is destroyed by absolute alcohol in five minutes. The experiments of Reinicke, Ahlfeld, Epstein, and others show that bacteria in a moist condition are quickly destroyed by a fifty-per-cent. solution of alcohol and that such a solution is more potent as a germicide than absolute alcohol, which has comparatively little germicidal power. For the disinfection of the hands a fifty-per-cent. solution is recommended by Epstein.

Solutions of mercuric chloride, carbolic acid, thymol and lysol in fifty-per-cent. alcohol were found by Epstein to be more active than aqueous solutions of the same strength. Alcoholic solutions have the advantage of dissolving oils and consequently of acting more promptly when the object in view is to disinfect the hands.

Ammonia.—The experiments of Koch show that ammonia does not destroy the spores of the anthrax bacillus; but, according to Behring, ammonia in solution in the proportion of 1 to 417 inhibits the growth of the anthrax bacillus. Gottbrecht also found that both ammonia and carbonate of ammonia have decided antiseptic properties. Rigler has proposed to use ammonia gas for the disinfection of rooms, and concluded from his experiments that it is a reliable disinfectant when used in the proportion of 1 kgm. of aqua ammonia, exposed in shallow vessels, for every one-hundred cubic feet of space. Moreno, who conducted a series of experiments in the laboratory of the University of Turin, was not able to confirm Rigler as to the value of this agent for practical use in infected apartments, and it is no doubt much inferior to formaldehyd and probably of less value than sulphur dioxid.

Ammonium Chloride.—A five-per-cent. solution failed in twenty-five days to destroy the vitality of anthrax spores (Koch).

Ammonium Sulphate.—A five-per-cent. solution was effective in five days, but failed in two days to destroy anthrax spores (Koch).

Aromatic Products of Decomposition.—Klein has tested the germicidal power of *phenyl proprionic* and of *phenyl acetic* acid. He finds that anthrax spores resist both of these acids in the proportion of 1 to 400 after two days' exposure; but anthrax bacilli, in the absence of spores, are quickly killed by a solution of this strength. Certain non-pathogenic micrococci were not killed by exposure for twenty-five minutes to a solution of 1 to 200. Exposure for ninety-six hours to these acids, in the proportion of 1 to 200, did not prevent the caseous matter of pulmonary tuberculosis from infecting guinea-pigs; 1 to 800 was effective in destroying the virulence of swine-plague virus.

Arsenious Acid.—A one-per-cent. solution destroyed the vitality of anthrax spores in ten days, but failed to do so in six days (Koch). The infective power of tuberculous sputum, as shown by inoculation into guinea-pigs, is not destroyed by twenty hours' exposure to a one-per-cent. solution.

Benzol.—Exposure for twenty days failed to destroy the vitality of anthrax spores (Koch).

Benzoic Acid.—This agent was found by De la Croix to destroy the bacteria of broken-down beef-tea in the proportion of 1 to 77, while 1 to 121 failed. A saturated aqueous solution failed to destroy anthrax spores in seventy days (Koch).

Boric Acid (boracic acid).—In the writer's experiments a saturated solution failed to destroy any of the test organisms—two species of micrococci and *B. termo.* A five-per-cent. solution failed in ten days to destroy anthrax spores (Koch). According to Arloing, Cornevin, and Thomas, the activity of the *fresh* virus of symptomatic anthrax is destroyed by 1 in 5 (twenty per cent.), the time of exposure being forty-eight hours.

The experiments of Pome and of Rideal show, also, that boric acid has no value as a germicide.

Bromine.—A two-per-cent. aqueous solution destroys the vitality of anthrax spores in twenty-four hours (Koch). Fischer and Proskauer have studied the action of bromine vapor upon various micro-organisms. They find that exposure for three hours, in a dry atmosphere, to three per cent. does not destroy the tubercle bacillus in sputum, or the spores of anthrax. But when the atmosphere is saturated with moisture 1 part in 500 is effective, and when the time of exposure is extended to twenty-four hours, 1 part in 3,500. Bromine vapor is the most active agent for the destruction of the virus of symptomatic anthrax (Arloing, Cornevin, and Thomas). It destroys the ferment of sour milk (*Bacterium lactis*) in the proportion of 1 to 348 (Molke). The bacteria of broken-down beef-tea are destroyed by 1 to 336 (De la Croix).

Butyric Acid.—Five days' immersion in this acid failed to destroy the vitality of anthrax spores (Koch).

Calcium Chloride.—A saturated solution has no destructive action on anthrax spores (Koch.)

Calcium Hydroxide.—According to Kitasato, the typhoid bacillus and the cholera spirillum, in bouillon cultures, are killed in four or five hours by the addition of 0.1 per cent. of calcium oxide. Liborius had previously reported still more favorable results, but his bouillon cultures were largely diluted with distilled water. From a practical point of view the experiments of Pfuhl are more valuable. Calcium hydrate was added to the dejections of typhoid patients. When added in the proportion of three per cent. sterilization was effected in six hours, and by six per cent. in two hours. When milk of lime containing twenty per cent. of calcium hydrate was used the results were still more favorable, the typhoid bacillus and cholera spirillum being killed in one hour by the addition of two per cent. of the disinfectant. The germicidal value of lime wash applied to walls has been determined by Jäger, silk threads soaked in cultures of various pathogenic bacteria were attached to boards and the lime wash was applied with a camel's-hair brush. Anthrax bacilli (without spores), the glanders bacillus, Staphylococcus pyogenes aureus, and several other pathogenic bacteria, were killed by a single application in twenty-four hours, but the tubercle bacillus was not killed by three successive applications. In the writer's experiments (1885) the typhoid bacillus and Staphylococcus pyogenes aureus were killed in two hours by a solution containing 1 to 40 of calcium oxide and 1 to 80 failed. Spores of the anthrax bacillus, and of several other species forming spores, were not killed by two hours' exposure to a milk of lime containing twenty per cent. of calcium oxide.

Camphor.—Alcohol saturated with camphor has no effect upon the fresh virus of symptomatic anthrax (Arloing, Cornevin, and Thomas).

Carbolic Acid.—Tested upon anthrax spores, Koch found a one-per-cent. solution to be without effect after fifteen days' exposure; a two-per-cent. solution retarded the development of spores, but did not completely destroy their vitality in seven days; a three-per-cent. solution was effective in two days. In the absence of spores, Koch found that a one-per-cent. solution quickly destroys the vitality of anthrax bacilli. The same author recommends a five-per-cent. solution for the destruction of the "comma bacillus" in the discharges of cholera patients, and a two-per-cent. solution for the disinfection of surfaces and articles soiled by such discharges. The writer has found that, in the proportion of 1 to 200 this agent destroys *B. termo* and a septic micrococcus (*M. Pasteuri*) in active growth, while 1 to 25 failed to destroy the bacteria in broken-down beef-tea. A micrococcus obtained from the pus of an acute abscess was destroyed by 0.8 per cent., while 0.5 per cent. failed. In all of these experiments the time of exposure was two hours. According to Salmon, the micrococcus of swine plague multiplies abundantly in urine containing one per cent. of carbolic acid, while the micrococcus of fowl cholera is destroyed by six hours' exposure in a solution of this strength (one-per-cent.). A two-per-cent. solution destroys the bacterium of symptomatic anthrax (dried virus) in forty-eight hours (Arloing, Cornevin, and Thomas). The bacteria in broken-down beef-tea are not destroyed by a ten-per-cent. solution (De la Croix).

Davaine showed, by inoculation experiments, that anthrax bacilli in fresh blood are destroyed by being exposed to the action of a one-per-cent. solution for one hour. Solutions in oil and in alcohol have been shown by Koch to be less effective than aqueous solutions. Thus a five-per-cent. solution in oil failed to destroy the vitality of anthrax spores in one hundred and ten days, and the same solution did not destroy the bacilli in the absence of spores in less than six days. A control experiment showed that olive oil alone was effective in the same time. A five-per-cent. solution in alcohol did not destroy anthrax spores in seventy days. Schill and Fischer found that the infecting power of tuberculous sputum, as shown by inoculation into guinea-pigs, is destroyed by twenty-four hours' exposure to a five-per-cent. solution. The same result was obtained with a three-per-cent. solution, while one and two-per-cent. solutions failed.

Behring (1890) reports that the bacillus of typhoid fever, of diphtheria, and of glanders, the spirillum of cholera and streptococci are destroyed in a few hours by a 0.5-per-cent. solution and in one minute by a 1.5-per-cent. solution. Staphylococci are more resistant and require a solution of from two to three per cent. The germicidal value of carbolic acid is increased by the addition of mineral acids to disinfecting solutions (Laplace), by sodium chloride (Scheurlen), and by heat.

Carbonic Oxide.—This gas has no effect upon bacteria, which freely develop in it (Hamlet).

Chloral Hydrate.—In the writer's experiments this agent was found to destroy micrococci in the proportion of twenty per cent., and to fail in ten-per-cent. solution, the time of exposure being two hours.

Chlorine.—Fischer and Proskauer have made an elaborate research with reference to the germicidal power of this agent, as tested by a variety of micro-organisms. In the absence of moisture these experimenters found that desiccated anthrax spores were not destroyed by exposure for an hour in an atmosphere containing 44.7 per cent. of this gas. When, however, the spores were moistened, an exposure for one hour in a *moist* atmosphere containing four per cent. of chlorine was effective, and by extending the time to three hours one per cent. sufficed to destroy the vitality of the spores. The anthrax bacillus, in the absence of spores, was killed by exposure in a moist atmosphere containing 1 part in 2,500, the time of exposure being twenty-four hours, and the same amount was effective for *Micrococcus tetragenus;* while the micrococcus of erysipelas and the micrococcus of fowl cholera were killed by 1 to 25,000 in twenty-four hours, and 1 to 2,500 in three hours. The bacillus of mouse septicæmia was destroyed in one hour by 1 to 200, and the same proportion was effective for the tubercle bacillus in sputum. In the writer's experiments, made in 1880, the bacteria present in urine which had been freely exposed to the air and had become putrid were destroyed by exposure for one hour in an atmosphere containing 1 to 400. Koch found that after immersion for twenty-four hours in chlorine water, anthrax spores do not develop in a suitable culture medium. Chlorine destroys the fresh virus of symptomatic anthrax, but is powerless against that which has been dried (Arloing, Cornevin, and Thomas). The bacteria of broken-down beef-tea are destroyed by 1 to 1,061 (De la Croix).

Chloride of Lime.—(See *Hypochlorites*).

Chloroform.—Immersion for one hundred days in chloroform does not destroy anthrax spores (Koch). This agent is without effect upon the virus of symptomatic anthrax (Arloing, Cornevin, and Thomas). One part to 1.22 failed to destroy the bacteria of broken-down beef-tea (De la Croix).

The more recent (1894) experiments of Behring show that in the absence of spores this agent quickly destroys bacilli and micrococci. He reports that in his experiments the cholera spirillum was destroyed by a one-per-cent. solution in less than a minute and the typhoid bacillus by a one-half-per-cent. solution in an hour.

Chromic Acid.—An aqueous solution of 1 to 100 does not destroy the spores of anthrax in two days (Koch).

Citric Acid.—In the writer's experiments upon micrococci from the pus of an acute abscess, twelve per cent. was effective and ten per cent. failed. Abbott reports that twenty-five per cent. failed to destroy the organisms in broken-down beef-tea, and the spores of *B. subtilis* and *B. anthracis*, but that 1.25 per cent. was active in the case of micrococci.

Creolin.—This is a mixture of the cresols emulsified with hard soap. According to Behring its germicidal value is considerably greater than that of carbolic acid, except when albumen is present in the material to be disinfected.

Creosote.—This agent was found by the writer to be fatal to micrococci in the proportion of 1 to 200. In the proportion of one per cent. it failed, after twenty hours' exposure, to destroy the tubercle bacillus in sputum (Schill and Fischer).

According to Yersin a saturated aqueous solution does not destroy the tubercle bacillus in cultures in twelve hours. Guttman in extended experiments upon various pathogenic organisms found that a solution of 1 to 300 is fatal to Bacillus pyocyaneus and to B. anthracis in one minute, and that 1 to 600 destroys the Finkler-Prior spirillum in the same time.

Cresol.—This is a coal-tar product obtained by the fractional distillation of crude carbolic acid. There are three forms, known as ortho-, meta-, and paracresol. A mixture of these is largely used for disinfecting purposes under the name of tricresol. A solution of cresol of 0.5 per cent. is said to be as efficient as a germicide as a two- or three-per-cent. solution of carbolic acid (Hammer). Neutral solutions are non-irritating. According to Gruber the germicidal value of the cresols is but little influenced by the presence of albumen. He found cresol to be three times as potent as carbolic acid for the destruction of Staphylococcus pyogenes aureus. The cresols are considerably less toxic than carbolic acid.

Cupric Sulphate.—This salt failed, in the writer's experiments, to destroy the spores of *B. anthracis* and of *B. subtilis* in two hours' time in a twenty-per-cent. solution. Arloing, Cornevin, and Thomas report that the dried virus of symptomatic anthrax is destroyed in forty-eight hours by a twenty-per-cent. solution. In Koch's experiments a five-per-cent. solution failed to destroy anthrax spores in ten days. The writer has found, however, that this salt is effective in the proportion of 1 to 200 for the destruction of micrococci, the time of exposure being two hours.

Ether.—Anthrax spores may germinate after being immersed in ether for eight days, but thirty days' exposure is effective for the destruction of these spores (Koch).

Eucalyptol.—The bacteria in broken-down beef-tea are not destroyed by 1 to 14 (De la Croix).

Ferrous Sulphate.—In the writer's experiments, reported in the *American Journal of the Medical Sciences* (April, 1883), a solution of twenty per cent. of this salt failed to destroy micrococci and the bacteria in broken-down beef-tea. In more recent experiments a ten-per-cent. solution was found to be fatal to *Micrococcus tetragenus*, but failed in the case of another micrococcus obtained from the pus of an acute abscess. Koch found that a five-per-cent. solution did not destroy anthrax spores in six days. According to Arloing, Cornevin, and Thomas, exposure to a twenty-per-cent. solution for forty-eight hours does not destroy the virus of symptomatic anthrax.

Ferri Chloridi Tinct.—In the writer's experiments a four-per-cent. solution was fatal to micrococci, and a two-per-cent. solution failed.

Ferric Chloride.—A five-per-cent. solution failed in two days to destroy anthrax spores, but was effective in six days (Koch).

Formaldehyd.—The experiments of Aronson (1892), Lehmann (1894), Philipp (1895), Rosenberg (1897), and others have demonstrated the germicidal value of formaldehyd. A forty-per-cent. solution of this gas in water is known under the name of formalin. According to Ascoli (1895) anthrax bacilli are killed in fifteen minutes by a ten-per-cent. solution of formalin and anthrax spores in five hours by the same solution. A five-per-cent. solution destroyed the diphtheria bacillus in ten minutes and Staphylococcus aureus in thirty minutes. Formaldehyd gas in the proportion of 1 to 100 in the air of a flask was found to destroy Staphylococcus aureus in forty-five minutes, and the micrococcus of pneumonia in fifteen minutes. Wilson (1897) and others have shown that the germicidal action of formaldehyd is considerably greater at a temperature of 37° C. and above than it is at a low temperature.

Formic Acid.—This acid, of the specific gravity of 1.120, failed in two days to destroy anthrax spores, but was effective in four days.

Gallic Acid.—Abbott finds this acid to be effective for the destruction of the organisms in broken-down beef-tea in the proportion of 2.375 per cent.; tested upon the spores of the anthrax bacillus and of *B. subtilis*, it failed in this proportion, the time of exposure being two hours. Micrococci were destroyed by 0.7 per cent., while 0.4 per cent. (1 to 250) failed.

Glycerin has no action upon the fresh virus of symptomatic anthrax (Arloing, Cornevin, and Thomas); and is inert as regards the spores of bacilli (Koch).

Heat.—(*a*) Dry heat. Werner, in 1879, found that putrefactive bacteria enveloped in dry cotton were destroyed by exposure for one hour to a temperature of 125° C. (257° F.). Wernich also experimented upon the bacteria of putrefaction, and found that exposure for five minutes to a temperature of 125° to 150° C. secured their destruction. The virulence of dried tuberculous sputum is not destroyed with certainty by exposure for one hour to 100° C. (Schill and Fischer).

Koch and Wolffhügel, as the result of an elaborate series of experiments, arrive at the following conclusions:

1. A temperature of 100° C. (212° F., dry heat), maintained for an hour and an half, will destroy organisms which do not contain spores.
2. Spores of mould fungi require for their destruction in hot air a temperature of from 110° to 115° C. (230° to 239° F.), maintained for an hour and a half.
3. Bacillus spores require for their destruction in hot air a temperature of 140° C. (284° F.), maintained for three hours.

(*b*) Moist heat. Davaine, in 1873, showed that the virulence of fresh anthrax blood which does not contain spores is destroyed by a temperature of 55° C. (131° F.), maintained for five minutes; or by 50° C. (122° F.) for ten minutes; or by 48° C. (118° F.) for fifteen minutes. The writer has fixed the thermal death point of several species of bacilli and micrococci at 60° C. (140° F.), the time of exposure being ten minutes. This temperature is also fatal to the micrococcus of swine plague, while the micrococcus of fowl cholera is destroyed by exposure for fifteen minutes to a temperature of 132° F. (Salmon). The destruction of spores is a very different matter, and requires a boiling temperature, maintained, in the case of some of these reproductive bodies, for several hours. But a temperature of 5° C. above the boiling point quickly destroys the most refractory spores. Thus the writer has found, as the result of repeated experiments, that this temperature—105° C. (221° F.)—maintained for ten minutes, is fatal to the spores of *B. subtilis*, and that the same temperature in two minutes' time destroyed the vitality of anthrax spores. Koch, Gaffky, and Loeffler also report that a temperature of 105° C. and upward, maintained for ten minutes, is fatal to all spores, as shown by their failure to develop in culture solutions. Where a temperature of 110° C. was reached, the experiment could be stopped, as no spores were capable of germinating after exposure to this temperature.

The tubercle bacillus is destroyed by a temperature of 70° C. maintained for ten minutes.

Hydrochloric Acid.—In experiments upon broken-down beef-tea, the writer found this acid to be effective in the proportion of fifteen per cent., and to fail at ten per cent. (two hours' exposure). One part in two hundred was found to destroy the virulence of septic blood (rabbit septicæmia), as proved by inoculation experiments. Anthrax spores are destroyed in ten days by a two-per-cent. solution, but not in five days (Koch).

In the experiments of Kitasato this acid in the proportion of 0.2 per cent. destroyed the typhoid bacillus in five hours. Boer found that the typhoid bacillus was destroyed by 1 to 300 in two hours, the diphtheria bacillus by 1 to 700, and the cholera spirillum by 1 to 1,350.

Hydrogen.—Bacteria may develop in an atmosphere of hydrogen (Hamlet).

Hydrogen Peroxide.—In the writer's experiments, a solution containing 3.98 per cent. of H_2O_2 was found to destroy the organisms in broken-down beef-tea in the proportion of thirty per cent. The same solution failed in twenty per cent. Tested upon a pure culture of *B. anthracis* containing spores, the same solution was effective at twenty per cent. (0.8 per cent. $H_2O_2=1$ to 125), and failed at ten per cent. Tested upon micrococci, ten per cent. was effective, and five per cent. failed. The solution used in these experiments contained five per cent. of sulphuric acid, and the germicidal power of this agent must be considered in estimating their value as determining the effect of H_2O_2 upon the vitality of the test organisms.

Gibier (1890) reports that solutions containing 1.5 per cent. of hydrogen peroxide destroy the anthrax bacillus, the bacillus of typhoid fever, Streptococcus pyogenes, and various other bacteria in a few minutes. Pave found that this agent in a one-per-cent. solution destroys spores in one hour and staphylococci in from ten to fifteen minutes.

Hypochlorites of Lime and of Soda.—Commercial chloride of lime contains from twenty to thirty per cent. of available chlorine, and Labarraque's solution of good quality from two to three per cent. According to Duggan, a solution containing 0.25 of one per cent. (1 to 400) of chlorine as hypochlorite is an effective germicide, even when allowed to act only one or two minutes, while 0.06 of one per cent. (6 to 10,000) will kill spores of *B. anthracis* and *B. subtilis* in two hours. These results are not in accord with those of Koch, who reports that a five-per-cent. solution of chloride of lime (value in available chlorine not given) failed in two days to destroy the vitality of anthrax spores, but was effective in five days. The development of the spores was, however, retarded by one day's exposure.

Indol.—When added to water in excess, failed in eighty days to destroy anthrax spores (Koch).

Iodine.—In the writer's experiments, iodine in aqueous solution with potassium iodide was found to be fatal to the micrococcus of rabbit septicæmia in the proportion of 1 to 1,000, and to a micrococcus obtained from the pus of an acute abscess in 1 to 500. De la Croix reports that 1 to 410 destroys the bacteria of broken-down beef-tea. Salmon found 1 to 1,000 to be fatal to the micrococcus of fowl cholera. "Iodine water" was found by Koch to destroy the vitality of anthrax spores in twenty-four hours. The same author reports that exposure for forty-eight hours to a two-per-cent. solution of iodine in alcohol failed to destroy anthrax spores, but that exposure in such a solution for five days was effective. In the experiments of Schill and Fischer, twenty hours' contact with a solution of the strength of 1 to 500 failed to destroy the virulence of tuberculous sputum, as tested by inoculation experiments.

Iodine Trichloride.—The germicidal value of this agent has been established by the experiments of Riedel (1887), of Behring (1890), and of Traugott (1893). The last-mentioned bacteriologist reports that a one-per-cent. solution will destroy in one minute the bacillus of typhoid fever and of diphtheria, the cholera spirillum, Streptococcus pyogenes and staphylococci.

Iodoform.—Dissolved in oil, in the proportion of five per cent., iodoform failed in an hour and a half to destroy tubercle bacilli in fresh sputum. A saturated solution in water also failed after twenty-four hours' contact; as did also a five-per-cent. solution in oil of turpentine (an hour and a half's exposure). No better results were obtained in an experiment in which the material was exposed for twenty hours to dry iodoform vapor, but in the presence of moisture dried sputum was disinfected in two hours. Mixing the sputum with moistened iodoform was also effective after twenty-four hours' contact (Schill and Fischer).

Iodol.—The writer has made experiments which show that bacteria are not destroyed by adding iodol in excess to culture solutions—probably because it is quite insoluble.

Labarraque's Solution.—(See *Hypochlorites.*)

Lactic Acid.—A five-per-cent. solution failed in five days to destroy anthrax spores (Koch). Abbott reports that a twenty-per-cent. solution of concentrated lactic acid (specific gravity 1.21) was effective for the destruction of the bacteria in broken-down beef-tea and the spores of *B. subtilis*, while fifteen per cent. failed. Upon anthrax spores lactic acid of the same strength failed in the proportion of fifty per cent. Micrococci were destroyed by a one-per-cent. solution, while 0.5 per cent. failed; time of exposure in these experiments, two hours. The bacillus of typhoid fever is killed in five hours by 0.4 per cent., the cholera spirillum by 0.3 per cent. (Kitasato).

Mercuric Chloride.—Koch's experiments (1881) gave the following results: A solution of 1 to 1,000 destroys anthrax spores in a few minutes, and 1 to 10,000 is effective after a more prolonged exposure. The writer (1884) obtained similar results—1 to 10,000 destroyed the spores of Bacillus anthracis and of Bacillus subtilis in two hours. More recent experiments indicate that failure to grow in culture solutions cannot be accepted as evidence of the destruction of vitality in the case of spores exposed to the action of this agent, unless due precautions are taken to exclude the restraining influence of the small amount of mercuric chloride which remains attached to the spores. Koch had ascertained that the development of spores is restrained by the presence of 1 to 300,000 in a culture medium, and Geppert has shown that even so small an amount as 1 to 2,000,000 will prevent the development of spores, the vitality of which has been reduced by the action of a strong solution (1 to 1,000). When this restraining action is entirely neutralized by washing the spores in a solution containing ammonium sulphide it requires, according to Geppert, a solution of 1 to 1,000 acting for one hour completely to destroy the vitality of anthrax spores. Fränkel found that a solution of 1 to 1,000 was effective in half an hour. The typhoid bacillus, the bacillus of mouse septicæmia, and the cholera spirillum, in bouillon cultures and in cultures in flesh-peptone-gelatin, are destroyed in two hours by 1 to 10,000; but in a bouillon culture to which ten per cent. of dried egg albumen was added a one-per-cent. solution was required to destroy the typhoid bacillus in the same time (Bolton). According to Van Ermengem, cultures of the cholera spirillum in bouillon are sterilized in half an hour by 1 to 60,000, but cultures in blood serum require 1 to 800 to 1 to 1,000. In experiments upon tuberculous sputum, Schill and Fischer found that exposure of fresh sputum to an equal amount of a 1 to 2,000 solution for twenty-four hours failed to disinfect it, as shown by inoculation experiments in guinea-pigs. The antiseptic power of mercuric chloride is given by Miquel as 1 to 14,300. In the writer's experiments 1 to 33,000 was found to prevent the development of putrefactive bacteria in bouillon, but a minute bacillus contained in broken-down beef infusion multiplied, after several days, in 1 to 20,000. The pus cocci were restrained in their development by 1 to 30,000.

In Behring's experiments the anthrax bacillus and cholera spirillum were killed in one hour by 1 to 100,000 when the temperature was 36° C., but at a temperature of 3° C. the proportion required was 1 to 25,000. The same author states that at 22° C. Staphylococcus aureus in bouillon is not always killed in twenty-five minutes by 1 to 1,000.

Abbott (1891) has shown that a 1 to 1,000 solution does not always destroy Staphylococcus pyogenes aureus in five minutes. He says: "Frequently all the organisms would be destroyed after five minutes' exposure, but almost as often a certain few would resist for that length of time, and even longer, going in some cases to ten, twenty, and even thirty minutes."

According to Yersin, a solution of 1 to 1,000 kills the tubercle bacillus in one minute.

The albuminate of mercury, as has been shown by Lister, is soluble in an excess of albumin, and, according to Behring, is just as effective as an aqueous solution containing the same amount of sublimate when dissolved in an albuminous liquid like blood serum (?).

In practice the addition of a mineral acid to sublimate solutions, or of sodium, potassium, or ammonium chloride, is to be recommended, to prevent the precipitation of the mercuric chloride by albumin in fluids containing it. Behring recommends the addition of five parts of sodium or potassium chloride to one of the sublimate. Such a solution is more stable than a simple solution of sublimate, and no precipitate is formed by the addition of alkalies or by albumin.

The same result is obtained, according to La Place, by the addition of five parts of hydrochloric or tartaric acid to one part of sublimate in aqueous solution.

Viquerat (1889) has made a comparative study of the germicidal value of mercuric chloride and mercuric iodide. The last-mentioned salt was found to be least efficient. A solution of 1 to 1,000 of bichloride killed the anthrax bacillus and the typhoid bacillus in five minutes; the same proportion of the biniodide required fifteen minutes to destroy these bacilli.

Mercuric Cyanide, $Hg(CN)_2$, and the *oxycyanide* of mercury have been tested, with the following results: Staphylococcus aureus is destroyed in five minutes by 1 to 100, in one hour by 1 to 1,000, in two hours by 1 to 1,500 (Chibret). The development of Bacillus anthracis in culture solutions is prevented by the presence of cyanide of mercury in the proportion of 1 to 25,000, and by the oxycyanide by 1 to 16,000 (Behring).

Boer obtained the following results with the oxycyanide —cultures in bouillon, twenty-four hours in incubating oven, time of exposure two hours:

	Restrained development.	Destroyed vitality.
Anthrax bacillus	1 to 80,000	1 to 40,000
Diphtheria bacillus	1 to 80,000	1 to 40,000
Glanders bacillus	1 to 60,000	1 to 30,000
Typhoid bacillus	1 to 60,000	1 to 30,000
Cholera spirillum	1 to 90,000	1 to 60,000

Nitric Acid.—This acid, in the proportion of 1 to 400, was found by the writer to neutralize the virulence of septic blood (rabbit septicæmia). In the proportion of eight per cent. it destroys the organisms in broken-down beef-tea, but failed at five per cent.

Kitasato reports that in the proportion of 0.2 per cent. the vitality of the typhoid bacillus and of the cholera spirillum is destroyed in four or five hours.

Nitrous Acid.—Exact experiments to determine the germicide value of this agent are wanting. The writer has tested it upon vaccine virus, and found that exposure for six hours, in an atmosphere containing one per cent., destroys the virulence of this material dried upon ivory points.

Oil.—Anthrax spores germinate after having been immersed for ninety days in pure olive oil (Koch).

Oil of Cinnamon.—According to Behring, oil of cinnamon is about three times as potent a germicide as carbolic acid. Omaltschenko (1891) has made extended experiments to determine the germicidal value of essential oils and places oil of cinnamon at the head of the list.

Oil of Mustard.—According to De la Croix, 1 to 40 destroys the bacteria of broken-down beef-tea. Koch found that ten days' immersion in an aqueous solution of this oil is not fatal to anthrax spores, but that in the proportion of 1 to 33,000 it restrains their development.

Oil of Peppermint.—A five-per-cent. solution in alcohol failed in twelve days to destroy anthrax spores, but the development of these spores is restrained by 1 to 33,000 (Koch).

Oil of Turpentine destroys anthrax spores in five days, but failed to do so in one day (Koch). Turpentine has no action upon the virus of symptomatic anthrax (Arloing, Cornevin, and Thomas). Koch has shown that the development of anthrax spores is retarded by 1 to 75,000.

Oleic Acid.—A solution of five per cent. in ether does not destroy anthrax spores in five days (Koch).

Osmic Acid.—A solution of one per cent. destroys anthrax spores in one day (Koch). No report with reference to weaker solutions.

Oxalic Acid.—This acid in saturated solution destroys the virulence of the fresh virus of symptomatic anthrax, but has no effect upon dried virus (Arloing, Cornevin, and Thomas). Abbott reports that this acid in five-per-cent. solution failed, in two hours, to destroy anthrax spores. But the spores of *B. subtilis* were killed by a one-per-cent. solution, and the organisms in broken-down beef-tea by 1.5 per cent. Micrococci resisted exposure for two hours to 1 to 1,000, but were destroyed by 1 to 400.

Oxygen.—The experiments of Pasteur upon the attenuation of virus show that long exposure to the oxygen of the atmosphere reduces the reproductive activity of the micrococcus of fowl cholera and of the anthrax bacillus, and that after a time the vitality of these organisms is destroyed. The spores of the anthrax bacillus are, however, unaffected by prolonged exposure. Paul Bert has shown that oxygen under pressure is fatal to bacteria.

Ozone.—The experiments of Chappius show that atmospheric organisms, collected upon a cotton filter, are destroyed by passing through this cotton filter, placed in a tube, a current of ozonized air.

Lukaschewitsch found in his experiments that 1 gm. in a cubic metre of air failed to kill anthrax spores in twenty-four hours. The cholera spirillum in a moist state was killed by this amount in twenty-four hours, but not in fifteen hours. Sonntag, in carefully conducted experiments, found that ozonized air passed over silk threads to which various pathogenic bacteria were attached failed to destroy these bacteria in twenty-four hours when the proportion of ozone was 4.1 mgm. per litre; when the amount was increased to 13.53 mgm. per litre the anthrax bacillus and Staphylococcus pyogenes albus failed to grow after twenty-four hours' exposure.

Picric Acid.—The bacteria of broken-down beef-tea are destroyed by 1 to 100 (De la Croix).

Potassium.—In the writer's experiments, caustic potash in the proportion of two per cent. was fatal to the micrococcus of rabbit septicæmia in one experiment, and failed in a second; eight per cent. failed to kill a micrococcus from pus, while ten per cent. was successful; ten per cent. failed to destroy the bacteria in broken-down beef-tea, and twenty per cent. was successful. Exposure to the action of a ten-per-cent. solution for twenty-four hours failed to destroy the tubercle bacillus in fresh sputum (Schill and Fischer).

According to Jäger 0.18 per cent. of potassium hydroxide kills the typhoid bacillus in four or five hours. The cholera spirillum is destroyed by 0.237 per cent. added to cultures (Kitasato).

Potassium Acetate.—A saturated solution of this salt failed to destroy anthrax spores in ten days (Koch).

Potassium Arsenite (Fowler's solution of).—In the writer's experiments this solution, in the proportion of forty per cent., failed to destroy micrococci from pus.

Potassium Bichromate.—A five-per-cent. solution failed in two days to destroy anthrax spores (Koch).

Potassium Bromide is without germicidal power.

Potassium Chlorate has no germicidal power. In the writer's experiments a four-per-cent. solution failed to destroy the micrococcus of rabbit septicæmia. A five-per-cent. solution failed in six days to destroy anthrax spores (Koch).

Potassium Chromate.—A five-per-cent. solution was without effect upon anthrax spores immersed in it for two days (Koch).

Potassium Iodide.—A solution of five per cent. does not destroy anthrax spores in eighty days (Koch). In the writer's experiments, exposure for two hours to the action of a saturated solution did not prevent the subsequent development of the organisms in broken-down beef-tea.

The cholera spirillum and the typhoid bacillus are destroyed by five hours' exposure in a solution containing 9.23 per cent. (Kitasato).

Potassium Nitrate.—A four-per-cent. solution was found by the writer to be without effect upon the micrococcus of rabbit septicæmia in fresh blood.

Potassium Permanganate.—The writer, in experiments with this agent, found that a two-per-cent. solution was required to destroy *M. Pasteuri* in the blood of a rabbit, but that a micrococcus from pus was killed by 1 to 833—time of exposure two hours. This difference depends upon the fact that the permanganate is quickly decomposed by the large amount of organic material in the blood used in the first experiments, and not upon a difference in resisting power in the two test organisms.

Further experiments showed that, in the absence of organic matter, micrococci are destroyed in two hours by solutions containing 1 to 1,000. Equal parts of a solution of 1 to 250 and of broken-down beef infusion, proved to be without effect. Anthrax spores were not destroyed by the same solution (1 to 250) in four hours, but in another experiment, in which the time was extended to four days, they failed to germinate. The spores of *B. subtilis*, however, were destroyed in two hours by a solution of 1 to 250. According to Arloing, Cornevin, and Thomas, a five-per-cent. solution destroys the fresh virus of symptomatic anthrax, but has no effect upon the dried virus. One per cent. was found by Koch not to destroy anthrax spores in two days, but five per cent. was effective in one day.

The glanders bacillus is destroyed in two minutes by a one-per-cent. solution (Löffler). The experiments of Jäger show that a one-per-cent. solution cannot be relied upon for the destruction of various pathogenic bacteria used as a test, but a five-per-cent. solution was effective for all except the tubercle bacillus.

Quinine.—One per cent., *dissolved with muriatic acid*, destroys the spores of anthrax in ten days' time (Koch). A ten-per-cent. solution of sulphate of quinine has no action upon the bacterium of symptomatic anthrax (Arloing, Cornevin, and Thomas). The writer has found that in the proportion of 1 to 800 to 1 to 1,000 quinine prevents the development of bacilli and micrococci, but its exact germicidal power for organisms of this kind, in the absence of spores, has not been determined.

Salicylic Acid.—In the writer's experiments this reagent was dissolved by means of sodium biborate, which by itself has no germicidal power. A two-per-cent. solution was found to destroy a micrococcus from pus and *B. termo* in active growth; four per cent. failed to destroy the bacteria in broken-down beef infusion. The virus of symptomatic anthrax is destroyed by forty-eight hours' exposure to a solution of salicylic acid of 1 to 1,000, and by a saturated solution in alcohol (Arloing, Cornevin, and Thomas). Salicylic acid dissolved in oil and in alcohol, in five-per-cent. solution, does not destroy anthrax spores (Koch); 1 to 200 destroys the bacteria of sour milk (Molke); 1 to 343 destroys the bacteria in broken-down beef infusion (De la Croix).

A solution of 2.5 per cent. kills the tubercle bacillus in six hours (Yersin). In the proportion of 1 to 300 it destroys the cholera spirillum in half an hour (Van Ermengem).

Skatol in excess in water has no germicidal action as tested upon anthrax spores (Koch).

Soda.—Caustic soda destroys the fresh virus of symptomatic anthrax in the proportion of 1 to 5, but has no effect upon dried virus (Arloing, Cornevin, and Thomas). A ten-per-cent. solution destroys the tubercle bacillus in dried sputum after twenty-four hours' contact (Schill and Fischer).

The experiments of Jäger show that sodium hydroxide has about the same germicidal value as caustic potash. Boer obtained the following results, the time of exposure being two hours: anthrax bacillus 1 to 450; diphtheria bacillus 1 to 300, glanders bacillus 1 to 150, typhoid bacillus 1 to 190, cholera spirillum 1 to 150.

Sodium Biborate.—In the writer's experiments a saturated solution was found to have no germicidal power. A twenty-per-cent. solution does not destroy the virus of symptomatic anthrax, as proved by inoculation experiments (Arloing, Cornevin, and Thomas); 1 to 12 failed to kill the bacteria in broken-down beef infusion (De la Croix). A five-per-cent. solution failed in fifteen days to destroy the vitality of anthrax spores (Koch).

Sodium Chloride.—In the writer's experiments a five-per-cent. solution failed to destroy the virulence of septicæmic blood. A saturated solution failed in forty-eight hours to destroy the virus of symptomatic anthrax (Arloing, Cornevin, and Thomas). A saturated solution failed, in forty days, to destroy the vitality of anthrax spores (Koch). A saturated solution failed, in twenty hours, to destroy the tubercle bacillus in fresh sputum (Schill and Fischer).

Sodium Hyposulphite.—The writer's experiments show this salt to be without germicidal power. In saturated solution it failed, in two hours' time, to destroy any of the test organisms. Exposure for forty-eight hours to a fifty-per-cent. solution does not destroy the virus of symptomatic anthrax (Arloing, Cornevin, and Thomas).

Sodium Sulphite.—The results obtained by the writer correspond with those reported in the case of sodium hyposulphite, being entirely negative.

Stannous Chloride.—Abbott reports that this agent is active in the proportion of one per cent. and failed in 0.8 per cent., the test being the organisms in broken-down beef infusion, and time of exposure two hours.

Sulphuric Acid.—In the writer's experiments this acid was found to be fatal to micrococci in the proportion of 1 to 200; but a four-per-cent. solution failed to destroy the bacteria in broken-down beef infusion, doubtless on account of the presence of reproductive spores. An eight-per-cent. solution was, however, found to be effective (strength of acid, 1.480 gm. H_2SO_4 in each cubic centimetre). Salmon has found that a solution of 1 to 200 is fatal to the micrococcus of fowl cholera. A solution of one per cent. failed to destroy anthrax spores in forty days (Koch).

The experiments of Boer show a considerable difference in the resisting power of various pathogenic bacteria. The time of exposure being two hours, the anthrax bacillus was destroyed by 1 to 1,300, the diphtheria bacillus 1 to 500, the glanders bacillus 1 to 200, the typhoid bacillus 1 to 500, the cholera spirillum 1 to 1,300.

Sulphur Dioxide.—Wernich, in 1877, found that the bacteria of putrefaction are not destroyed by the presence of 3.3 volumes of sulphur dioxide in one hundred of air, when exposed upon strips of cotton or woollen goods saturated with putrid liquids. But four to seven per cent. was effective in six hours' time. Schotte and Gärtner, in 1880, found that strips of thick woollen goods soaked in culture liquids containing the bacteria of putrefaction were not disinfected by exposure in a chamber in which sulphur was burned in the proportion of 92 gm. per cubic metre (about six volumes per cent. of SO_2). Koch exposed various species of bacilli containing spores in a disinfection chamber for ninety-six hours, the amount of SO_2 at the outset of the experiment being 6.13 volumes per cent., and at the end of ninety-six hours 3.3 per cent. The results were entirely negative. The writer has also made numerous experiments which show that this agent is without power for the destruction of spores. Even when liquid SO_2 is poured upon the spores of anthrax or of *B. subtilis*, they germinate freely when transferred to a suitable culture medium. But this agent, especially in the presence of moisture, destroys micrococci and bacilli which do not contain spores. Thus, Koch found that the anthrax bacillus obtained from the spleen of a mouse recently dead, and exposed, while still moist, upon a silk thread, in an atmosphere containing one volume per cent. of SO_2, was destroyed in thirty minutes. In one of Koch's experiments the amount of SO_2 in the disinfection chamber was at the outset 0.84 per cent., and at the end of twenty-four hours 0.55 per cent. An exposure of one hour, in this experiment, destroyed anthrax bacilli (still moist) upon silk thread. Four hours' exposure failed to destroy the vitality of *Micrococcus prodigiosus* growing upon potato, but twenty-four hours' exposure was successful. The same result was obtained with the bacteria of blue pus. In experiments with an aqueous solution of SO_2, Koch found that five days' immersion in a solution containing 5.718 per cent. by weight was required to destroy the vitality of anthrax spores. A solution containing 11.436 per cent. by weight failed to kill anthrax spores in twenty-four hours, but was successful in forty-eight hours. According to Arloing, Cornevin, and Thomas, sulphur dioxide does not destroy the bacteria of symptomatic anthrax which contain spores. The writer's experiments show that micrococci are destroyed, even in the absence of moisture, when they are exposed for eighteen hours in a bell jar containing twenty volumes per cent. of SO_2. When the proportion was reduced to four volumes per cent. the result was not uniform, the test organisms—micrococci—were destroyed in some cases, and in others were not. In experiments with an aqueous solution of SO_2 the following results were obtained: The presence of 1 to 2,000, by weight, destroyed a micrococcus obtained from the blood of a patient with vaccinal erysipelas, and 1 to 4,000 failed; the same result was obtained with micrococci obtained from a vaccine vesicle, and with another species obtained from the blood of a patient having puerperal septicæmia.

Thoinot (1890) as a result of numerous experiments arrives at the conclusion that the bacillus of tuberculosis, of glanders, of diphtheria, of typhoid fever, and the spirillum of cholera are all destroyed by exposure for twenty-four hours in an atmosphere containing SO_2 developed by the combustion of sixty grains of sulphur per cubic metre of air space.

Sulphureted Hydrogen.—Bacteria develop readily in the presence of sulphureted hydrogen (Hamlet).

Sulpho-carbolates. — In experiments upon anthrax spores, Koch found that a five-per-cent. solution of sulpho-carbolate of zinc was effective in five days, while sulpho-carbolate of soda failed in five-per-cent. solution to destroy these spores after ten days' contact.

Tannic Acid.—The writer found, in his experiments, that a solution of one per cent. in half an hour is fatal to *M. Pasteuri* in the blood of a rabbit. A twenty-per-cent. solution has no effect upon the virus of symptomatic anthrax (Arloing, Cornevin, and Thomas). A five-per-cent. solution failed in ten days to destroy anthrax spores (Koch). A twenty-per-cent. solution failed in two hours to destroy the spores of *B. anthracis* or of *B. subtilis*, but was effective upon the organisms in broken-down beef-tea. Micrococci are destroyed by 1 to 400, while 1 to 800 failed (Abbott).

Tartaric Acid.—A twenty-per-cent. solution was found by Abbott to be effective, in two hours, for the destruction of organisms in broken-down beef infusion, but the same proportion failed with anthrax spores and with those of *B. subtilis.* Micrococci did not multiply in culture solutions, after exposure to 0.25 per cent., but one-half this amount (1 to 800) failed.

Thymol.—An alcoholic solution of 1 to 400 was found by the writer to destroy *M. Pasteuri* in fresh blood. One part in twenty is fatal to the bacteria in broken-down beef infusion (De la Croix). A five-per-cent. solution in alcohol does not destroy anthrax spores in fifteen days, but the development of these spores is retarded by a solution of 1 to 80,000 (Koch).

The tubercle bacillus is destroyed by contact with thymol for three hours (Yersin). Thymol has about four times less germicidal power than carbolic acid (Behring).

Valerianic Acid.—A five-per-cent. a solution in ether failed in five days to destroy anthrax spores (Koch).

Zinc Chloride.—In the writer's experiments, *M. Pasteuri* failed to develop after exposure for two hours to 1 to 200, while a micrococcus obtained from gonorrhœal pus required for its destruction a solution of two per cent. The spores of *B. anthracis* are not destroyed by two hours' exposure in a ten-per-cent. solution. A five-per-cent. solution was, however, found to be effective in the same time in the case of *B. subtilis* spores, and upon the organisms in putrid beef-peptone solution. Koch's experiments are in accord with the above, in showing the superior resisting power of anthrax spores. He found that after being immersed in a five-per-cent. solution for thirty days, these spores still germinated freely. The development of *M. prodigiosus* was found by the same author to be only slightly retarded by exposure for more than sixteen hours to the action of a one-per-cent. solution.

Zinc Sulphate.—In the writer's first experiments with this agent, a solution of twenty per cent. failed in two hours to destroy micrococci obtained from the pus of an acute abscess. In later experiments a micrococcus from the same source resisted exposure for the same time to a ten-per-cent. solution, while *M. tetragenus* was destroyed by a 1 to 10 solution. Broken-down beef infusion, mixed with an equal quantity of a forty-per-cent. solution, was not sterilized after two hours' contact. In Koch's experiments anthrax spores were found to germinate after having been immersed for ten days in a five-per-cent. solution. *George M. Sternberg.*

GERM LAYERS.—It has long been known that the bodies of embryos consist of distinct layers, which in many cases are separable from one another, so as to be recognized in gross as discrete membranes. It is now known that all such layers may be reduced to three primitive ones, named the ectoderm, mesoderm, and entoderm (by certain writers, epiblast, mesoblast, and hypoblast). The ectoderm is a layer of epithelium; so also is the entoderm; the mesoderm is more complex. In the lower animals, the mesoderm is less developed than in the higher forms; in the hydroids the body is constituted mainly by the two epithelial layers, the ectoderm covering the outside of the body, and the entoderm lining the digestive cavity; there is very little space between them, the space being occupied by the slightly developed mesoderm. As we ascend the scale the mesoderm increases gradually, constantly acquiring a greater predominance, until in mammals nearly the whole bulk consists of mesoderm. But, in spite of this change, the three layers are preserved throughout, and their essential relations are not altered, so that we are able to assert the unity of organization throughout the whole series of multicellular animals, without which it would be impossible to accept the doctrine of evolution. The demonstration, therefore, of the homologies of the germ layers, is the most important morphological generalization since the establishment of the cell doctrine. As these homologies have already been discussed under *Gastrula,* and also the metamorphoses of the layers under *Fœtus,* it only remains for us to review, with precision and brevity, the rôle of the layers in the construction of the human body.

The ectoderm covers the external surface of the body, and persists in adult life as the stratified epithelium (epidermis) of the skin; it forms, of course, all the so-called epidermal structures—hairs, nails, sebaceous and sweat glands, lens, cornea, etc. It also lines part of the buccal cavity; and the buccal portion gives rise to the hypophysis cerebri, to the enamel organs of teeth, and probably to all the salivary glands. It forms a small invagination to meet the rectum, so that it also lines the anus. It gives rise to the entire nervous system by producing the medullary canal, which makes the central nervous system, and from which grow out all the nerves, and probably all the peripheral ganglia, and from which also grows out the evagination which makes the optic nerve, the retina, the choroid, and the epithelial portions of the iris. It forms the epithelium of the olfactory and nasal cavities, and the epithelium of the auditory labyrinth.

The entoderm [also spelled "endoderm"] forms the epithelium which lines the digestive tract, including the surface of the tongue; also the epithelium of the trachea and lungs, and of all the glands appended to the respiratory passages, and to the digestive tract, including the thyroid, pancreas, and liver. The liver cells, it should be remembered, constitute a true though much modified epithelium. The notochord is developed from the entoderm.

The mesoderm may be conveniently divided into three portions—the mesenchyma, the mesamœboids, and the mesothelium (*cf. Coelom*). 1. The *mesenchyma* produces all the connective tissues of the body, and includes therefore the cutis, the non-epithelial walls of the alimentary tract, etc.; tendons, cartilage, and bone, the marrow of bones, lymph glands, and spleen; it produces also the blood-vessels and blood, the entire lymphatic system proper, and the heart. Pigment cells, fat cells, and smooth muscles are derived from the mesenchyma also. 2. The *mesamœboids* include the leucocytes and wandering cells, and perhaps the embryonic red blood cells, and the marrow cells. 3. The *mesothelium* is the epithelium of the cœlom; it produces the peritoneal and pleural epithelia, the striated muscles (myotomes), except those of the heart, and all the non-mesenchymal tissues of the entire urogenital apparatus, except, of course, the external genitalia. (Spee traces the Wolffian duct to the ectoderm.)

Now, in classifying organs, it is best to rank them as belonging to that layer from which their functionally essential and characteristic part is derived. Thus, although the pancreas, ovary, and spinal cord all contain connective tissue, we do not call them mesodermal, but respectively entodermal, mesothelial, and ectodermal. The gland cells of the pancreas come from the entoderm; the ova and the Graafian follicles come from the mesothelium; the ganglion cells and nerve fibres (axis cylinders) from the ectoderm. Adopting this principle, we may classify the organs of the human body as follows:

ECTODERMAL.

- Skin (epidermis).
- Epidermal structures:
  - Hair,
  - Nails,
  - Glands:
    - Sebaceous,
    - Sudorific,
    - (Salivary ?),
    - (Thymus ?).
  - Corneal epithelium,
  - Lens of eye.
- Central nervous system:
  - Nerves,
  - Ganglia.
- Eye, optic vesicle:
  - Optic nerve,
  - Retina, etc.
- Olfactory organ.
- Auditory organ.
- Lining of mouth:
  - Teeth,
  - Hypophysis.
- Anus.
- Chorion:
  - Placenta.
- Amnion:
- (Wolffian duct ?).

MESODERMAL.

1. Mesenchyma:
   - Connective tissue:
     - Cutis, etc.,
     - Tendons,
     - Cartilage,
     - Bone,
     - Marrow.
   - Lymph glands.
   - Spleen.
   - Blood-vessels:
     - blood (in part).
   - Lymphatic system,
   - Fat cells,
   - Smooth muscle.
2. Mesamœboids:
   - Leucocytes,
   - Embryonic red blood cells,
   - (Marrow cells ?).
3. Mesothelium:
   - Peritoneum,
   - Pleuræ,
   - Urogenitals:
     - Wolffian body,
     - Kidney,
     - Testis,
     - Ovary,
     - Oviduct:
       - Uterus,
       - Vagina.
   - Striated muscles.

ENTODERMAL.

- Epithelium (of digestive tract):
  - Thyroid,
  - Trachea and lungs,
  - Œsophagus,
  - Stomach,
  - Liver,
  - Pancreas,
  - Intestine,
  - Yolk sac,
  - Cœcum,
  - Vermix,
  - Colon,
  - Rectum,
  - Allantois:
    - (Bladder).
- Notochord.

The human body may be defined as two tubes of epithelium, one inside the other; the outer tube, epidermal or ectodermal, is very irregular in its form; the inner tube, entodermal, is much smaller in diameter, but much longer than the outer, and has a number of branches (lung, pancreas, etc.), and is placed within the ectodermal tube. Between these two tubes is the very bulky mesoderm, which is divided by large cavities (abdominal and thoracic) into two main layers, one of which is closely associated with the epidermis and forms the body wall, the somatopleure of embryologists; the other joins with the entoderm to complete the walls of the splanchnic viscera, and constitute the splanchnopleure of embryologists. The mesoderm is permeated by two sets of cavities: (1) the heart and blood-vessels; (2) the lymphatic system. It is also differentiated into numerous tissues, muscle, tendon, bone, etc., and organs, urogenital system. The nervous system, although developed from the ectoderm, is found separated from its site of origin, and completely encased in mesoderm.

As we ascend the animal scale, we discover in all parts an increasing complexity; especially in the nervous system is this marked, but it is even more strikingly shown by the evolution of the mesoderm in relative size and differentiation. This important correspondence between the organization of the mesoderm and the degree of evolution of animals has not, to my knowledge, hitherto attracted express attention.

Charles Sedgwick Minot.

GESTATION.—The word is derived from the Latin verb *gestare* to carry, and therefore describes the function performed by the pregnant woman from the time of the fecundation of the ovum to that of delivery. Gestation and pregnancy are synonymous, but most authors do not apply either term to those pathologic conditions characterized by prolonged retention of a dead fœtus or secundines.

The German synonym *Schwangerschaft* expresses this same idea of carrying something; the French *grossesse* refers to the increase in the size of the abdomen during pregnancy; the Italian *gravidanza*, like the English terms *gravid* and *gravidity*, imply an increase in the weight of the uterus (*gravo*, to weigh down).

When more than one fœtus is present the gestation is designated as *multiple*, in distinction from a *single* or *simple* pregnancy. Normally the ovum should develop within the uterine cavity, and all other forms of gestation are known as *ectopic*, viz., out of place. In this article the subject of ectopic gestation will not be considered.

MODIFICATIONS CAUSED BY GESTATION.—The presence of the fecundated ovum at once stimulates the maternal organism, and a series of changes take place in order to meet the following requirements: 1. A place must be provided in which the fœtus can develop and be protected. 2. There must be a physiologic hypertrophy of all organs concerned in the processes of nutrition and excretion. 3. There must be preparations for labor and subsequent nourishment of the child. Under these heads will fall all the local and general changes induced by gestation, but as the genital system is the centre of physiologic disturbance it is there we expect to find the most striking modifications.

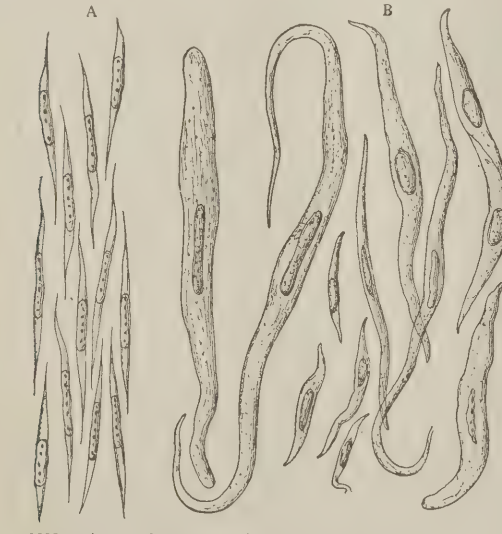

FIG. 2289.—*A*, Muscle-elements from Non-pregnant Uterus; *B*, cells from uterus shortly after delivery. (Sappey.)

Uterus—Modifications of its Body.—Increase in the size of the womb in order to keep pace with the growing demands of the fœtus constitutes one of the most prominent features of gestation. The volume of the uterus augments gradually, but not regularly, the growth during the later months being more rapid than at first. Of course the size of the uterus at term varies somewhat, depending upon the size of the fœtus, the number of children in utero, and the amount of liquor amnii; but the following figures give a general idea of the extent of uterine enlargement:

Before impregnation the uterus weighs about an ounce, its capacity is about one cubic inch, and the length of the cavity is two and one-half inches. At term the uterus weighs two pounds, has a capacity of four hundred cubic inches, and its cavity measures fifteen by ten by nine inches.

The increase in size is due chiefly to hypertrophy of all the constituents of the organ, and occurs, although in a less degree, even when the ovum develops outside of the uterine cavity. During the latter part of pregnancy distention undoubtedly plays a rôle in producing the uterine tumor.

Changes in the Form, Position, and Direction of the Uterine Body.—At first the uterus preserves its pyriform shape, but the gradual increase in its antero-posterior diameter gives it a spherical outline during the third and fourth months. From the fifth month onward the expansion of the fundus and lower uterine segment alters the sphere into an ovoid with the larger end up. Herrgott ("Essais sur les differentes variétés de forme de matrice pendant la gestation et l'accouchement," Strasbourg, 1839) found that the fundus of the uterus rarely took on a symmetrical development, but that the right half usually contained the breech and was more elevated than the left. The anterior portion of the lower segment is more developed than the posterior so that the axis of the uterine body passes in front of the cervix.

The enlargement of the uterus necessitates a change of position, especially as the organ soon becomes too large for the pelvic cavity. Many books describe a descent during the early weeks of gestation, but Tarnier and Pinard never have noted this downward movement except as a part of that pathologic condition known as prolapse. During the first months of gestation the gravid state of the uterus tends to exaggerate the normal anteflexion, and after the fourth month, when the fundus emerges from the pelvis, the degree of anteflexion is regulated by the position of the woman and the tonicity of the abdominal walls.

It usually is stated that by the fifth month the fundus has reached half-way to the umbilicus; by the sixth that it is on the level of the umbilicus, and that by the eighth, or eight and a half, the fundus lies under the ensiform cartilage. Pinard, however, says that the fundus usually is much higher than is described by most authors, and that he never found a uterus whose fundus was not above the umbilicus at the fifth month of gestation. On the other hand, Ribemont-Dessaignes mentions a case in which, at the sixth month, he found the fundus below the level of the umbilicus, the child weighing over seven pounds at birth. A possible explanation of these discrepancies may lie in the fact that the umbilicus is not a fixed point. At some time during the last two weeks of gestation the presenting part slips into the brim of the pelvis and the fundus sinks. In multiparæ this readjustment may be quite sudden and give rise to a sensation of "lightening," but it is much more gradual in primiparæ owing to greater rigidity of the abdominal walls.

The fundus of the uterus seldom lies in the median line of the abdomen. On examining 100 women at the ninth month of pregnancy P. Dubois and Pajot found a right lateral deviation in 76, a left in 4; in the remaining 20 the fundus lay in the median line. Not only does the fundus tend to fall to the right, but the body of the uterus rotates so that the left side is turned to the front. Probably both the deviation and the torsion proceed from the same cause; the distended sigmoid and rectum prevent the uterus from balancing upon the prominent vertebral column and push the organ toward the right; as the uterus rolls into the concavity at the right of the spine the right face becomes posterior. Unless this physiologic torsion of the uterus is remembered at the time of performing the operation of Cesarian section, the surgeon is in danger of making his incision into the left border of the uterus and severing some of the large vascular trunks lying in that region.

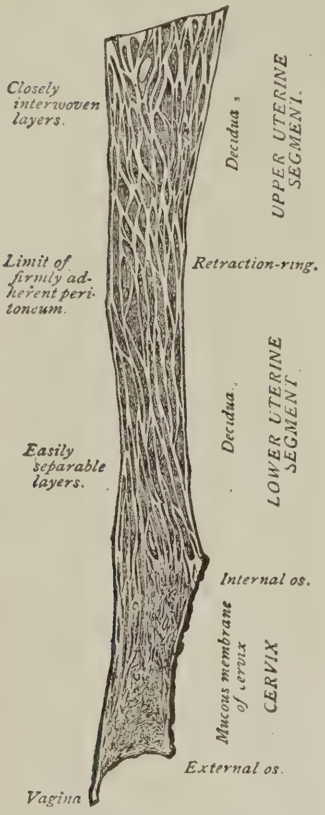

FIG. 2290.—Section of Wall of Pregnant Uterus. (Hofmeier.)

Changes in the Structure of the Uterus.—All the constituents of the uterus are involved in the process of development. There is marked hyperplasia of the serous coat, allowing the peritoneum to cover the uterus at the different stages of enlargement. The muscular fibres in the walls are greatly increased in size, but it is not proved that a true hyperplasia occurs. In the pregnant womb three layers of muscular fibres can be demonstrated. The superficial layer is made up of longitudinal and transverse fibres, which are continuous with those upon the surfaces of the tubes and round ligaments. The median layer forms the bulk of the uterine walls and contains interlacing fibres running in all directions. This layer is traversed by numerous vascular trunks around which the muscular fibres take an arciform direction. In the case of the veins, the external and middle coats of the vessels disappear so that the blood is conveyed in muscular channels lined by endothelial cells and known as sinuses. By the constricting action of these arciform fibres, which Pinard calls *ligatures vivantes*, hemorrhage is prevented after labor. The internal muscular layer is very thin and best marked by circular fibres at the orifices of the tubes, although a set of longitudinal and transverse fibres may be found just beneath the mucous membrane. In the lower uterine segment there is a predominance of longitudinal muscular fibres.

The advent of pregnancy stimulates the mucous membrane of the uterus so that it becomes congested, thickened, and thrown up into folds. The hypertrophy is the result of an increase in the interglandular tissue and a growth of the cellular layer in which may be found the large decidual cells of Friedländer. The superficial, or *compact layer*, of the decidua vera is in contact with the ovular decidua by the third month and then rapidly atrophies; it is through the deeper, or *spongy, layer* that the line of separation runs when the decidua is cast off.

All the blood-vessels of the uterus become much enlarged, and at the placental site the arteries empty directly into the lacunæ, the blood spaces penetrated by the villi. The veins form the uterine sinuses as described above and constitute an extensive plexus. The lymphatics are increased both in size and in number, communicating freely with those of the peritoneum and adnexa, an arrangement which readily explains the seriousness of puerperal infection and the ease with which it occurs. Nerve cells and trunks take part in the general hypertrophy. Keiffer (*Gaz. hebdom. de Méd. et de Chir.*, June 7th, 1900) claims that the uterus has a set of independent nerve cells which are found along the vessels and can be detected by Golgi's method of staining. These local ganglia have sensory, motor, secretory, and glandular functions, giving to the uterus an independence similar to that of the heart.

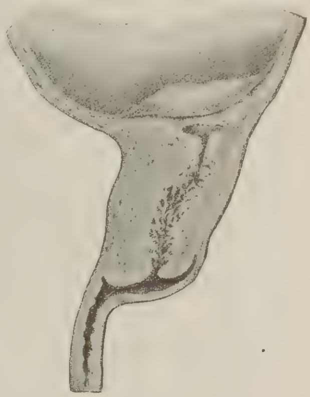

FIG. 2291.—Cervix in the Fifth Month of Pregnancy. (Leopold.)

During the first part of gestation the general hypertrophy of the tissues gives the uterine walls a thickness of five-eighths of an inch, but later distention reduces this measurement to one-quarter of an inch. Instead of being firm and unyielding, as are the walls of the virgin uterus, the tissues of the gravid womb are elastic and permit the fœtal movements, or a change in the woman's position, to alter the outline of the organ.

Modifications of the Cervix.—The hypertrophy of the cervix is much less marked than is that of the body of the uterus and is mostly completed by the fifth month of gestation. The mucous membrane of the cervix takes no part in the formation of the decidua, but the glands secrete a quantity of mucus which securely plugs the canal from the beginning of gestation. In primiparæ the form of the cervix is that of a cone with its apex down; in multiparæ the cone has its base down. In primiparæ, during the latter months of gestation when the presenting part lies low down and against the anterior wall of the

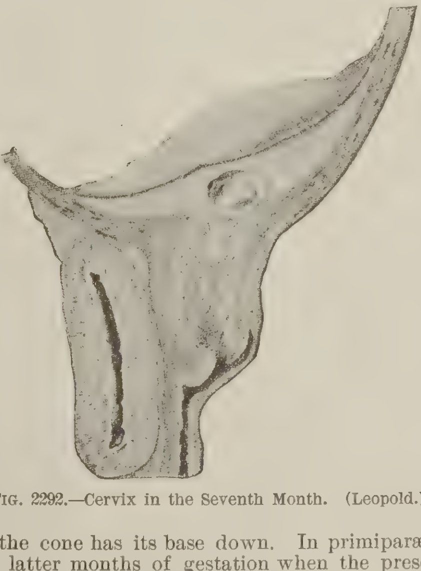

FIG. 2292.—Cervix in the Seventh Month. (Leopold.)

lower uterine segment, the external os may be carried so high into the hollow of the sacrum that students find it difficult to reach the cervical opening. The increased vascularity leads to a progressive softening of the cervix beginning at its most dependent portion; the softening is more marked and develops more rapidly in multiparæ than in primiparæ.

Physiologic Modification of the Uterus.—Associated with these anatomic changes certain physiologic properties appear. The *irritability* of the uterus increases, so that contractions are more easily evoked; this property is particularly marked at the menstrual epochs, so that at these times the danger of abortion is much increased. As the musculature of the uterus increases contractions become evident; during the latter months of gestation these contractions take place every twenty or thirty minutes; they are involuntary, slow and intermittent, differing from the contractions of labor in that they cause the woman no suffering nor have any effect upon the cervix. This systematic exercise of the uterine muscle serves to keep the organ in training for the exertions of labor. *Retractility* is a property more conspicuous during labor than during gestation; it enables the muscular fibre to hold a small portion of its contraction and remain permanently shortened. Retraction is thus dependent upon contraction and is seen at its best in the third stage of labor when the uterine sinuses are held securely closed after the contractions have ceased.

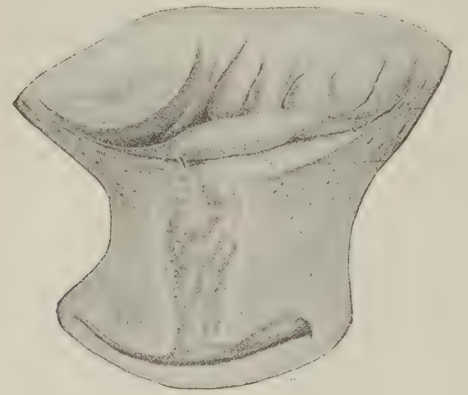

FIG. 2293.—Cervix in Ninth Month. (Leopold.)

Modifications of the Adnexa.—As the fundus rises into the abdominal cavity it necessarily elevates the uterine attachments of the round ligaments, broad ligaments, ovarian ligaments and tubes, bringing these structures into closer relation to the sides of the uterus and causing them to run in a more vertical direction. The round ligaments, tubes, and ovarian ligaments, having muscular fibres continuous with those of the uterus, take part to some extent in the general hypertrophy of the sexual organs. The folds of the broad ligaments become widely separated by the increased thickness of the uterine body.

Modifications of the Vagina and Vulva.—The congestion of the vaginal walls results in their hypertrophy and the mucous membrane becomes reduplicated and softened, favoring subsequent dilatation of this portion of the genital canal. There is often so little contrast between the feel of the softened vaginal wall and that of the cervix that the inexperienced student finds it very difficult to distinguish the one from the other. The engorgement of the vaginal vessels leads to an unusual amount of glandular secretion and produces a bluish coloration. There is relaxation and gaping of the vulva together with dilatation of the veins and increased secretion from the glands.

Modifications of the Pelvic Joints.—During pregnancy the interarticular cartilages of the pelvis become vascular and softened and allow a limited amount of motion in the joints, thus slightly facilitating the passage of the head during labor. The sacrococcygeal and symphysis pubis are the joints having the greatest degree of motility.

Modifications Produced Mechanically by the Enlarged Uterus.—The pressure of the growing uterus is apt to interfere with the functions of the bladder and rectum so that vesical irritation and constipation are often features of gestation. Owing to the diminished space within the abdomen a full bladder will cause a decided prominence of the anterior abdominal wall. Interference with venous return may produce or aggravate varicosities of the veins of the rectum, vulva, and lower extremities. When the fundus has reached the ensiform cartilage pressure upon the diaphragm interferes with respiration, particularly at times of exertion; as a compensation the thorax increases in width. The distention of the abdominal walls results in the formation of *striæ gravidarum*, which are bluish or reddish lines caused by the stretching and atrophy of some of the connective-tissue fibres in the skin. In time these striæ become pearly white in appearance so that there is a marked contrast between the scars of an earlier and those of a recent pregnancy. In severe cases of distention the recti muscles may separate and allow the fundus to fall forward and be covered only by the skin and peritoneum. By the seventh month of gestation the umbilical depression is obliterated, and during the last weeks of pregnancy there may be a protrusion of the navel. As the uterine tumor becomes large the woman can maintain her equilibrium in the upright position only by bending backward the upper portion of her trunk in order to bring the centre of gravity in a vertical line passing through the pelvis; hence her characteristic gait and posture.

Modifications of the Breasts.—The close relationship between the pelvic organs and the mammary glands explains the early and prominent changes found in the breasts: even in the second month there is an increase in size from the deposit of fat and growth of glandular tissue The enlarged lobules give a nodular feel on palpation, and when the tension of the skin is pronounced striæ form similar to those on the abdomen. The superficial veins are conspicuous and the areola, particularly in primiparæ and brunettes, becomes pigmented and shows elevations marking the sites of fifteen or eighteen sebaceous glands, known as Montgomery's follicles. By the fifth month the breast changes are at their height and a secondary areola may form having the appearance of a network of pigment containing numerous lighter spots. The nipple is hypertrophied, more sensitive and erectile; after the third month stroking the breast from the periphery inward may express a few drops of colostrum.

Modifications of the Circulatory System.—In order to carry out the new requirements laid upon the organism the quantity of blood is augmented during pregnancy and the increase is more marked in the watery constituents of the blood so that the red corpuscles are relatively diminished. The white corpuscles are said to be both relatively and actually increased in number. Many observers report an hypertrophy of the left side of the heart, accounted for by the increased labor of driving a greater amount of blood over a more extensive area, but recently this cardiac alteration has been questioned and deemed the exception rather than the rule. According to the studies of P. Longe the pulse during gestation has more tension and on the average shows a rate of 86 beats per minute.

Modifications of the Digestive System.—Nausea and vomiting are not uncommon during the first three months of gestation and the appetite may become capricious; later both the appetite and power of digestion are increased with the result that by the end of gestation the pregnant woman makes a gain equal, on the average, to one-thirteenth of her body weight. There is an increase of the amount of adipose tissue causing the figure to become fuller and rounder and serving as a reserve store of potential energy. This activity in metabolism entails greater activity in the excretory functions of the liver, lungs, skin, kidneys, and bowels.

Pigmentation of the skin is a common occurrence in pregnancy; besides the darkening of the areola there may be irregular spots upon the face and almost invariably there is a pigmented line extending from the symphysis pubis to the navel, known as the *linea nigra*.

Upon the inner surface of the skull are formed the "puerperal osteophytes," consisting of deposits of carbonate of calcium, phosphates, and organic matter.

The nervous system of the pregnant woman is extremely impressionable and often conditions of fretfulness or irritability develop. In rare instances the entire disposition changes and the patient shows unusual likes and dislikes.

MULTIPLE FŒTATION.—When the uterus contains two or more fecundated ova the pregnancy is designated as multiple or pluriparous.

Statistics as to the frequency of multiple gestation vary considerably among different writers. A fair statement would give the proportion about as follows: twins once in 120 pregnancies; triplets once in 7,900; quadruplets once in 370,000.

Among the factors predisposing to multiple pregnancy heredity and multiparity are important, but great stature, race, and the size of the ovaries also are mentioned among the causes.

Usually the fecundation of the ovules occurs as the result of a single coitus, but the instances on record in which a negress has given birth to one black and one white twin prove that the ovules discharged at the same menstrual epoch may be fecundated successively; to such cases the term superfecundation is applied. By superfœtation is meant the fecundation of ovules belonging to different periods and, theoretically, this form of superimpregnation would seem to be impossible both because ovulation is assumed to be suspended during pregnancy and because in the third month the ovular and uterine decidua come into contact, thereby preventing the access of the spermatozoon to the ovum. On the other hand, a few instances are reported in which women have given birth to apparently full-term children with a five-month interval separating the two. In the demonstrated absence of bifidity of the uterus such facts are difficult to explain on any other ground than superfœtation.

In twin conception the ova may have been discharged from different ovaries or both from the same ovary and even from the same ovisac. When twins develop from one ovum it must contain two germinating vesicles. In about sixty-six per cent. twins are of the same sex.

In all cases of multiple fœtation there is at first a separate amnion for each child, although later the partition may become absorbed or rupture, so that the children are found in the same sac at the time of labor; there are as many chorions as ova. The placentæ are originally distinct, but later the contiguous borders may fuse and an anastomosis of vessels occur; if one fœtal heart be much stronger than the other there is a disproportion in the amount of placental tissue at the disposal of the two children. The weaker fœtus may die and be so pressed upon by the survivor that it is flattened out against the walls of the uterus and forms what is known as a "fœtus papyraceous." The weight and size of twins usually are under the average and they are less likely to live than single children. Also the distention of the uterus makes premature labor more likely to occur in multiple pregnancies, and the distention is all the greater from the fact that hydramnios frequently is associated with twin pregnancy. According to Pinard's statistics out of 150 twin cases there were 108 premature deliveries.

DIAGNOSIS OF PREGNANCY.—The diagnosis of pregnancy rests upon maternal and fœtal signs; these are obtained by questioning and by inspection, palpation, and auscultation.

Subjective Signs.—Absence of menstruation usually is the first symptom noticed by the woman herself, and this sign is particularly valuable in those patients who always have been regular and in whom there is no evidence of general disease. Of course, amenorrhœa has no significance before puberty, after the menopause and during lactation. It also must be remembered that the fear of conception sometimes produces a "psychical amenorrhœa," and that in other instances the patient purposely has made false statements in the hope that an abortion will be accidentally induced. The amenorrhœa often associated with obesity has led the physician into embarrassing errors as the increase in the patient's size seems to confirm his diagnosis. Although Pinard says he never yet has observed a case of gestation in which menstruation persisted, a few instances have been reported in which a regular monthly flow occurred throughout a portion or the whole of pregnancy. Usually such periodic flowing does not have the features of normal menstruation, and is found to have its origin in cervical disease or ectopic pregnancy. It is not at all uncommon for a woman to have one period of diminished flow even after fecundation has taken place and the history of such a scanty discharge is almost as significant as amenorrhœa.

Nausea and *vomiting* on rising in the morning are mentioned as classic signs of early gestation, and certain multiparæ can make a positive diagnosis on these symptoms alone; salivation and heartburn may be associated with this gastric disturbance. Before allowing "morning sickness" to carry much weight the physician must eliminate all other reflex causes. The absence of gastric symptoms is of no value in excluding the possibility of pregnancy.

After the third month the patient notices a progressive increase in the size of her abdomen; the alleged preliminary flattening of the hypogastric region rests on no clinical basis. During the last two weeks multiparæ experience "*lightening*" or the feeling of relief produced by the marked sinking of the fundus.

Quickening is the term used to describe the sensations imparted to the mother by the fœtal movements and appears at variable times according to the experience and acuteness of feeling on the part of the patient. In some women the fœtal movements seem to be absent or unnoticed and in a few quickening occurs as early as the third month, but on the average the symptoms appear at the eighteenth or twentieth week. It is possible for even experienced matrons to be deluded and mistake muscular contractions or the passage of gas in the bowels for movements of the fœtus. A woman who once starts with the assumption of pregnancy is quite apt to experience all the confirmatory subjective signs and may succeed in leading her physician to a wrong conclusion.

Other less important signs which should not be passed over are: a sense of enlargement and tingling in the breasts, a feeling of heat in the pelvis with more or less leucorrheal discharge, irritability of the bladder, and constipation, also nervous disturbances such as neuralgia, dizziness, and change of disposition.

Objective Signs.—Pigmentation of the face, enlargement of the abdomen, and the peculiar carriage or gait may be noticed by the physician in the first few moments of the interview.

Abdominal Examination.—After having obtained the history of the case it is best to proceed next to the examination of the abdomen; by adopting this order we can make the investigation of the breasts and pelvic organs less of a shock to susceptible patients. For the abdominal examination the woman should be in the dorsal position with the knees drawn up and the surface of the body exposed from the ensiform to the symphysis: corsets and all constricting bands must be loosened and the bladder and rectum empty.

Inspection.—On inspection there should be noticed the size and shape of the abdominal tumor which usually extends more to the right than the left of the median line; during a uterine contraction the tumor becomes more prominent. If the fœtal movements are vigorous a series of irregular and temporary elevations are visible at times over the surface of the distended abdominal wall. During the latter half of gestation the umbilicus may be level with the surface or protruded. Pigmentation, in spots or along the median line, together with striæ are the other signs noted on inspection.

Palpation.—For palpation the hands should be warmed and laid flat upon the surface of the abdomen; the best results will be obtained by a series of circling motions punctuated by deeper pressure. Violent and sudden thrusts will cause a reflex contraction of the muscles and defeat the ends of the examination. The edge of the hand should be pressed down above the apparent site of the fundus and carried toward the symphysis in order to map out the upper limits of the uterus and obtain some idea of the period of gestation. The fundus is at the umbilicus at the sixth month; three fingers' breadth above at the seventh; half-way to the ensiform at the next month, and under the ensiform at the last month. If the fundus is slightly below the ensiform there may be several weeks of pregnancy remaining or "lightening" may have taken place and the labor be imminent. The peculiar doughy, semi-elastic feel of the uterus should be noted, and its increased firmness during a contraction constitutes *Braxton Hicks' sign*, which can be obtained as soon as the organ is large enough to grasp. By the sixth month the fœtal parts can be palpated and the smooth back, as well as the irregular bosses forming the shoulders, knees, or elbows, located. By pressing the fingers deep down at the sides of the superior strait the head can often be grasped between the two hands, or it may be felt as a hard, globular body lying at the fundus to the right of the median line. The breech is softer, less movable, and bears no relation to the shoulders. In thin women a hand or a foot can be grasped. During the course of palpation the physician usually feels upon the palms of his hands several distinct taps which are caused by the movements of the fœtal extremities; sometimes the entire body of the child will change its position under his hands.

External ballottement is obtained by placing a hand on either side of the abdomen and attempting to throw the fœtus, as it were, from one side to the other; or, in a breech presentation, the head will rebound from one hand to the other. If the woman be turned upon her side so that the prominent abdomen projects over the edge of the table the fœtus may be pushed up by a hand underneath and then fall again against the fingers. Ballottement depends upon the amount of fluid within the uterus and is best marked in cases of hydramnion, provided the fœtus be large enough to detect. In normal circumstances it is a sign belonging to the fifth and sixth months as previous to these times the child is too small, and in the latter months of gestation the liquor amnii, relative to the bulk of the fœtus, is not sufficient to allow of free motility.

Auscultation.—Percussion belongs under this head. Over the mass of the tumor there is dulness, while above and to the sides the coils of intestines give rise to tympanitic resonance. Usually the fœtal heart-sounds cannot be heard before the fifth month, except in favorable cases when experienced observers have detected them as early as the fourth. The rate of pulsation varies between 120 and 160, the sound being compared to that of a watch ticking under a pillow. The idea that a slow rate indicates a male and a rapid a female does not hold good in practice. In the most frequent presentations the head occupies the pelvis with occiput to the front, therefore the maximum intensity of the heart-sounds usually is found below the umbilicus and more often on the left side than the right; in posterior positions of the occiput the sounds are heard further round on the flank. When the head is at the fundus the focus of intensity is above and to one or the other side of the umbilicus.

In performing auscultation it is well to begin by applying the ear direct to the abdomen, using a thin towel for covering the skin, and examine systematically the four regions about the umbilicus. Many observers can do better by this immediate method of auscultation, besides which it is well to train the ear. The stethoscope should be used in those cases in which it is more convenient and pleasant or when the ear alone does not give satisfactory results. In order to hear distinctly the room must be very quiet, the physician's posture must be comfortable and not be such as to cause compression of the veins of his neck. A rapid maternal pulse may be misleading until its rate is compared with that of the pulsation in the radial artery; in some cases the observer will become conscious of his own heart beats, which, of course, are much slower than those of the fœtal heart.

The *uterine souffle* is heard over the left border of the uterus, which has been brought to the front by the torsion of the organ. It is a blowing sound like that of an anæmic murmur and is synchronous with the maternal pulse. The *uterine souffle* or *bruit* may be heard as early as the fourteenth week and is caused by the blood flowing through the enlarged uterine vessels; it is not peculiar to pregnancy and is often noted over large tumors.

The *funic souffle* is caused by some obstruction in the vessels of the umbilical cord, as from coiling about the neck. This sound is synchronous with the fœtal heart; it is not present in the majority of cases and appears during the latter half of gestation.

Sometimes the movements of the fœtus can be heard on auscultation as early as the fourth month of pregnancy as a succession of faint thuds or slight rubbing sounds. Gas in the bowel will closely simulate fœtal shock.

Examination of the Breasts.—The clothing already being well loosened it is easy to pass next to the search for mammary signs. On *inspection* the presence of striæ, enlarged veins, and pigmented areolæ are noted. *Palpation* detects the knotty feel, and by a little manipulation a drop or two of colostrum may be pressed from the nipple.

Examination of the External and Internal Genitals.—For the vaginal examination the patient is drawn down to the edge of the table, her clothing well pulled up and replaced by a sheet. For internal examination an empty bladder and rectum are more essential conditions than for abdominal palpation. In obscure cases and when the patient is very nervous an anæsthetic is indispensable. Disinfection of the examining hand must be a preliminary step before its introduction, and with the other hand the vulva should be held apart so that no contamination can be carried up from below.

Vaginal Touch.—As the finger passes up the vagina the velvety feel and moisture of the walls are noted. Next, the shape of the cervix and the presence or absence of softening must be determined. Goodell says that if the tip of the cervix feels like the end of one's nose the patient probably is not pregnant; if it feels as soft as one's lips there probably is a fœtus in utero. By bimanual examination the position, shape, size, and consistence of the uterus are discovered. During the fifth and sixth months *internal ballottement* can be obtained, especially in those cases in which the head presents. To develop this sign the internal finger is placed in front of the cervix and a quick push given to the fœtus; the physician will be sensible of the upward movement and subsequent return of the presenting part. By conjoined manipulation the uterine contractions may be detected as early as the third month.

Besides the softening of the cervix there are two valuable signs belonging to the first part of gestation. One is the marked angle formed by the corpus and cervix and easily noted on internal examination; the other is known as Hegar's sign and consists in the compressibility of the lower uterine segment. To obtain this sign the outside and internal fingers should compress the uterus just above the cervix. In well-marked cases there will seem to be no tissue at this point and the fundus and cervix will give an impression of being two disconnected bodies. Another way of bringing out Hegar's sign is to introduce the forefinger into the rectum and the thumb of the same hand into the vagina; while the outside hand presses down the uterus the internal thumb and finger grasp the organ just above the cervix. R. von Braun-Fernwald (*Wien. klin. Wochenschrift*, March 9th, 1899) describes a sign which he has found to be valuable in the diagnosis of early pregnancy. It consists in an asymmetry of uterine development detected by the bimanual examination. The ovum very rarely lies exactly in the centre of the uterine cavity at first and consequently the antero-posterior diameter of one horn is greater than that of the other; often a groove is perceptible between the two sides of the uterus.

Inspection.—As the finger is withdrawn from the vagina the parts are held open for a moment and the color of the vulva and lower vaginal wall is observed. A port-wine color of the mucous membrane may be noted, but is not a positive sign of pregnancy; the same color may be seen on the cervix if a speculum be introduced.

Value of the Different Signs and Symptoms of Gestation.—No one of the maternal signs or symptoms is positive, but the presence of a number of them forms a strong chain of circumstantial evidence. It is well known that all the breast signs may be present in a case of uterine disease and that uterine or abdominal enlargement may be due to the presence of a tumor. Before the sixth week a diagnosis of pregnancy is rarely positive, but strong opinion can be based upon the association of the following signs: amenorrhœa in a healthy married woman who has always been regular, an enlarged pyriform uterus of doughy consistency with a marked angle between corpus and cervix, softening of the cervix with compressibility of the lower segment. The pathognomonic signs of pregnancy come from the fœtus and are fœtal heart-sounds, ballottement, and fœtal movements; provided fallacies be excluded any one of these signs establishes the diagnosis. The Röntgen rays are of no use for early diagnosis, although late in gestation they have given information concerning the presentation and the condition of the mother's pelvis.

DIFFERENTIAL DIAGNOSIS.—Early gestation must be differentiated from those conditions which cause uterine enlargement; advanced pregnancy from those producing abdominal distention. *Fibroid enlargement* usually fails to give the uterus the shape and consistency belonging to pregnancy; the rate of increase in size does not correspond with that shown by the gravid uterus; there is menorrhagia rather than amenorrhœa. *Chronic metritis* presents many of the same differential points. *Hæmatometra* is a rare condition caused by the retention of menstrual blood within the uterus. Symptoms denoting pain and disturbance appear at puberty and are repeated each month but are unattended by flowing; an examination often discloses an obstructed vagina. The abdominal enlargements with which pregnancy has been confounded are those produced by *fat, tympanites, ascites, ovarian* and *fibroid* tumors.

Fat.—The amenorrhœa of obesity must be remembered. The thickness of the abdominal wall may be estimated by lifting a fold of tissue and also by observing the general fat-deposit of the patient. There are no uterine signs of pregnancy. As an adipose condition greatly interferes with bimanual examination it may be necessary to administer an anæsthetic in order to detect intra-abdominal conditions.

Tympanites.—Thorough cleansing of the bowels will diminish the size of the tumor which is resonant instead of dull.

Ascites.—When the patient lies in the dorsal position the tumor has a characteristic shape, namely, flattened on top and bulging at the sides. Fluctuation is marked and the change of position on the part of the patient changes the physical relations of flatness and resonance.

Ovarian Cyst.—An ovarian tumor may cause symmetrical enlargement of the abdomen but usually is unaccompanied by amenorrhœa; Braxton Hicks' sign is absent and fluctuation may be obtained. Of course no fœtal signs are present and the uterus usually is found to be displaced and not enlarged.

Fibroid Tumor of the Uterus.—A large fibroid usually is very irregular in outline and has a history of longer duration than that of pregnancy; menorrhagia usually is a prominent symptom.

It is important to remember that although various pathologic conditions may be present pregnancy is not necessarily excluded. There are many instances in which an operator has found gravidity associated with a fibroid or ovarian tumor.

Pseudocyesis.—Spurious pregnancy, or phantom tumor, is a condition met with in some women who are very desirous of having children as well as in those who dread maternity. There are instances in which women after the menopause have deluded themselves with the idea of pregnancy and made all the preparations for confinement. In these cases the physician can obtain an almost complete subjective history in which he may place undue reliance if the patient already has had experience in bearing children. Abdominal distention usually is present but due to the accumulation of gas or fat. It is said that often under an anæsthetic the tumor of pseudocyesis will disappear and the test should be made in doubtful cases. Under no circumstances should a physician make a diagnosis of pregnancy on the statements of the patient, nor must he allow them to give his mind a bias; in fact he should never give a positive opinion until signs from the fœtus are clearly manifest, although, before this time, he may feel justified in advancing a probable diagnosis.

DIAGNOSIS OF MULTIPLE PREGNANCY.—Having established the existence of pregnancy the presence of more than one fœtus in utero is indicated by the following signs: the uterus is larger than it should be for the estimated period of gestation; it is broader in proportion to its length than is the case in a single pregnancy; a multiplicity of fœtal parts is present; two hearts are heard, having different rates of pulsation and foci of intensity.

DIAGNOSIS OF DEATH OF THE FŒTUS.—When the death of the fœtus occurs in utero usually the contractions of the organ expel its contents, but there are cases in which the dead products of conception are retained and undergo saponification, mummification, putrefaction, or even become totally absorbed. The diagnosis of fœtal death may be very difficult and the signs vary according to the period of gestation at which it occurs. Lactation may be present for a few days and the subjective symptoms of gestation usually disappear. Except when there are profound disturbances following putrefaction there are no general symptoms distinctive of fœtal death and the diagnosis rests upon the results of physical examination. During the first half of gestation palpation, performed at intervals, reveals no increase in the size of the uterus and often a diminution; the softening of the cervix disappears. While comparisons are valuable, if the case is not seen until some time after the death of the fœtus, there may be great difficulty in making a diagnosis of pregnancy. During the second half of gestation the absence of certain fœtal signs, especially if they have been present, is most valuable. The patient no longer feels the movements of the child, nor can the physician detect the fœtal heart-sound; the absorption of the liquor amnii leads to diminution in the size of the uterus. If the head of the fœtus can be palpated, either in the lower uterine segment or at the fundus, crepitus may be obtained owing to the motility of the loosened bones of the skull. It is claimed that in all cases the urine of the woman contains acetone.

Care must be taken not to make an error in concluding that the fœtus is dead, for the fœtal movements may be absent because the intra-uterine space has become so limited and the heart-sounds may appear to be wanting merely because the physician is unable to find them. Usually considerable study of the case is required before any positive opinion can be formed. In a case of multiple pregnancy the diagnosis of the death of one child alone usually is impossible.

Duration of Gestation.—Even when the date of the fruitful coitus is known the duration of the pregnancy is found to vary from two hundred and sixty to two hundred and ninety-four days; in the majority of cases, however, confinement takes place at the end of two hundred and seventy-one days. For practical purposes it is found convenient to estimate the duration of pregnancy as two hundred and eighty days and count from the beginning of the last menstrual flow. This method is fairly reliable except when the conception occurred just previous to the first missed menstrual period. Labor is apt to take place on or near the tenth menstrual epoch, and to estimate this date we count back three months from the date of the first day of the last period and add seven days. Every visiting list generally contains a table which enables the physician to make his prediction in a given case. If the date of the last menstrual period is not available other data are the time of quickening and mensuration of the uterus. The period of quickening is not at all a fixed one but an approximate estimate of the day of confinement can be made by adding twenty-two weeks to the date of quickening. Mensuration of the uterus is very uncertain, as the size and number of the fœtuses vary and the amount of liquor amnii is not always the same. The position of the fundus at the different months has been stated.

Hygiene and Management.—Gestation being a physiologic condition a pregnant woman needs to do little more than observe the rules for normal living, but as derangements readily occur she should be under the supervision of her physician from the beginning to the end of gestation.

Diet.—No rules can be given for diet during pregnancy as, in normal cases, the patient may be allowed to follow her inclinations, provided she takes a sufficient quantity of nutritious food and avoids what is indigestible. During the early months when nausea and vomiting are present the diet should be simpler than usual. Breakfasting in bed and the use of some alkaline gastric sedative are sufficient for the ordinary case of stomach disturbance.

Clothing.—In order to avoid all pressure upon the growing uterus the clothing should be quite loose and the corset omitted; garters constricting the veins of the legs are objectionable. If the abdominal walls are relaxed so that the uterus drops too far forward a light well-fitting supporter should be worn.

Exercise.—Walking in the fresh air is the best form of exercise; horseback riding or any form of activity which entails straining or jolting should be forbidden. Long journeys in the cars are liable to induce abortion, especially if taken at the menstrual epochs. Those women who are accustomed to work hard for a living seem less easily disturbed and pass through the period of gestation without making any change in their daily life until the abdominal tumor acts as a mechanical hindrance. The pregnant woman requires a large supply of oxygen, so she should remain in the open air as much as possible and avoid all crowded or ill-ventilated rooms.

Rest.—An abundance of sleep is essential for the welfare of the gravid woman, and during the last part of gestation she should take a large amount of rest. Pinard's observations show that those patients who work close up to the time of their confinement bring forth children of less weight and vigor than do those woman who enter the hospital a month or six weeks previous to labor.

Bathing.—The gravid state does not prevent the woman from taking her daily bath, but on the contrary is an additional reason why she should keep the function of the skin as active as possible. Care, however, must be taken not to have the water at so low a temperature as to produce shock.

Hygiene of the Pelvic Organs.—On account of the increased secretion frequent bathing of the external genitals is required. If there be any affection of the vagina or cervix, so that leucorrhœa is troublesome, warm vaginal irrigations are indicated, care being taken not to inject the water with too much force. Gonorrhœal inflammation calls for active treatment on account of the danger to the child's eyes during delivery and the risk to the mother should the infection ascend. Sexual intercourse during pregnancy is an abnormality and by producing congestion may lead to an abortion.

Care of the Breast and Nipples.—During the last three months of gestation the nipples should be gently scrubbed daily with a soft nail-brush, water, and castile soap, after which a little albolene or cocoa butter should be applied. This course of treatment will toughen the nipples and at the same time keep them pliable. Exposure to the air, as by leaving the nightdress open, also is supposed to render the nipples less sensitive. If they are flattened or retracted they should be drawn out daily by means of the thumb and finger or by applying a breast-pump. Careful preparations for the function of lactation do much to add to the comfort of the woman after confinement.

Attention has been called to the fact that the nervous system of the pregnant woman is in a most susceptible state. Without entering into the much debated subject of the influence of maternal emotions upon the fœtus, it is quite certain that some nervous impressions of the mother have an unfavorable effect upon the child as well as upon her own well-being. Therefore it is wise to make every effort to surround the patient with a pleasing environment and to remove, as far as possible, all sources of irritation.

Urinary Examinations.—From the beginning of pregnancy it is the duty of the physician to keep himself informed as to the state of the woman's urine. At first the examination should be made every fortnight, but during the last two months of pregnancy every week; any abnormality will call for more frequent attention. The examination should be based on the twenty-four-hour sample, and the estimation of the urea and total solids is of the utmost importance. A great many pregnant women are troubled with leucorrhœa sufficient to contaminate the urine and give the test for albumin; therefore it is well to direct the patient to take a vaginal douche and introduce a tampon of absorbent cotton just before urinating; a string tied to the tampon makes removal easy.

Obstetric Examination.—As soon as the fœtus is viable, the physician should make an examination of the uterus and pelvis; the diameters of the superior and inferior straits should be measured; the size of the fœtus estimated and note taken whether the uterine enlargement corresponds to the supposed period of gestation. Some time during the last month of gestation a second examination should be carried out in order that the physician may be thoroughly informed as to the presentation and condition of the birth canal at the time of labor.

Pathology of Gestation.—Under this head will be considered the important pathologic conditions brought about by the gravid state itself and not the effect of gestation upon disease already existing.

Toxœmia of Pregnancy.—Gestation is a time of increased metabolism, for the woman must build up the uterine structures as well as nourish the fœtus, hence the greater the amount of waste-products to be eliminated. During pregnancy the excretory organs of the patient, particularly the bowels, liver, and kidney, undergo a physiologic hypertrophy and the poisonous substances of retrograde metamorphosis are removed before a dangerous degree of accumulation takes place. What is known as the toxæmia of pregnancy is an auto-intoxication due to deficient elimination and may arise in several ways.

The pressure of the enlarging uterus may hinder the proper performance of the functions of the eliminating organs, the waste-products being prepared for excretion and yet remaining locked up within the body. In other cases the intoxication occurs through the fault of the transforming organs, particularly the liver, which fail to reduce the waste matter to a chemical structure appropriate to the cellular activities of the eliminating tissues. Pinard looks upon the auto-intoxication of pregnancy as hepato-toxæmia, and Bouffe de Sainte Blaise (*Med. Rev. of Rev.*, June, 1899) mentions the following as diagnostic features of deficient hepatic action: progressive decrease in the quantity of urea with increase in the proportion of uric acid and such intermediate substances as leucin and tyrosin; alimentary glycosuria, *i.e.*, if the woman ingests a fixed amount of glucose a portion will appear in the urine owing to the impairment of the glycogenic function; there is urobilinuria and the toxicity of the blood serum is increased. The chemistry of auto-intoxication is not yet elucidated, but it is apparent that, whatever the source of the toxins, their presence irritates the tissues and establishes a circulus vitiosus.

Predisposing Causes.—Women who suffer from insufficiency of elimination while in the non-pregnant state may not be able to meet the added demands of gestation.

Such conditions as hydramnion, multiple pregnancy, and primiparity are attended with the greatest amount of intra-abdominal pressure and thus interfere to the greatest degree with the action of the liver, intestines, or kidneys; multiple pregnancy at the same time adds a large amount of waste material. It is during the latter months of gestation that the intra-abdominal pressure is most marked and the amount of waste matter coming from the fœtus at its maximum.

Symptoms and Diagnosis.—The circulation of an increased amount of toxins affects particularly the nerve centres and gives rise to such symptoms as headache, dizziness, irritability, and disturbances of vision; vomiting and diarrhœa are not uncommon and represent efforts at elimination. Auto-intoxication constitutes the prodromal state of eclampsia and the majority of the so-called disorders of pregnancy belong to its symptomatology.

The modifications of the urine in toxæmia are extremely important. The total amount passed in the twenty-four hours usually is much diminished and the elimination of urea lessened. Although urea probably is not the most important poison concerned in the production of the toxic condition, the amount present in the urine affords us a valuable index of elimination. In a normal quantity of urine the urea, according to Davis, should be from 1.4 to 2 per cent.; below one per cent. lies the danger zone. Jewett has pointed out the fact that eclampsia very rarely develops when the daily amount of urine is over three pints and that a large amount of urine, say seventy ounces in the twenty-four hours, will eliminate the poisons even when the tests show a diminished quantity of urea. These facts confirm the importance of making quantitative estimations of the urine in all cases of gestation. In normal pregnancy the toxicity of the urine in relation to that of the blood serum is much increased, but when symptoms of toxæmia appear the toxicity of the blood serum is heightened while that of the urine is diminished.

Albuminuria.—This is a common symptom of toxæmia, but it must also be remembered that albumin is present in five per cent. of all cases of pregnancy, as a rule not appearing until the latter months of gestation. Allbutt does not believe that pressure is an important cause of albuminuria, as the renal veins are not easily pressed upon and albumin often is absent when the pressure is greatest; he thinks that the poisons absorbed from the intestinal canal are responsible for the kidney disturbance. Under all circumstances albuminuria calls for treatment, as there has been established a definite relation between this condition and a lessened development of the fœtus; albuminuria frequently has been found associated with hemorrhages into the placenta. Vallois (*L'Obstétrique*, No. 6, November 15th, 1899) reports two cases of albuminuria during pregnancy which were not severe nor permanent and were treated by a milk diet, yet were followed by fœtal death and expulsion. In both these cases the placentæ were found to be the seats of numerous hemorrhages. According to Jewett albuminuria is present in from eighty to ninety per cent. of eclamptic patients previous to the first convulsion.

Treatment of Toxœmia.—The plain indications are to diminish the amount of waste and stimulate elimination. The diet should be simplified: in mild cases it is sufficient to cut off all meat and heavy articles of food. In the severe cases and whenever there is marked albuminuria, the patient must confine herself to an exclusive milk diet. It is very uncommon for women to become eclamptic who have been upon a milk diet for two or three weeks. The milk may be taken hot or cold, and the addition of a little salt, a few drops of coffee, or some effervescing mineral water will suit some tastes.

All the emunctories should be called into play to increase elimination, and one of the advantages of the milk diet is its diuretic action. Water should be given freely either by mouth or per rectum; irrigations of the bowel with saline solution have a valuable effect upon the kidney and at the same time cleanse the intestinal canal. The use of salines each morning, with occasional doses of calomel at night, will stimulate the action of the bowels, and the skin should be made active by the use of hot-air baths, massage, and the adoption of flannel underclothes. The energy of the treatment must be proportionate to the severity of the symptoms. Abundance of fresh air is a necessary part of the treatment and the inhalations of oxygen seem to do good in many cases.

If, in spite of the preventive treatment, the symptoms continue and the condition of the urine does not improve the artificial induction of abortion or premature labor is indicated.

Vomiting.—A certain amount of gastric disturbance during the first months of pregnancy is so common that "morning sickness" has become one of the presumptive signs of the gravid state. What is designated as *simple vomiting* appears very early in gestation, perhaps during the first week or two, and ceases about the end of the third month. The patient may become nauseated and vomit on first arising in the morning or the stomach may remain quiescent until food is taken; in a few cases the vomiting takes place only at night; in others the attacks of emesis are scattered irregularly throughout the day, the vomited matter consisting of mucus, bile, and ingested food. The distinctive feature of simple vomiting is that the patient's general nutrition suffers little or not at all and the affection ceases spontaneously, having had no influence upon the course of the pregnancy.

Pernicious or Uncontrollable Vomiting—Hyperemesis.—Whenever the gastric disturbance becomes so severe that the health of mother and child is threatened it may be classed as *pernicious*. Simple vomiting may merge into the uncontrollable form by the symptoms becoming more and more intense. The patient rejects the simplest form of food or drink and in consequence makes fewer and fewer attempts at ingesting food. In the classic description of the disease by Dubois three stages are described, but it is very rare that the divisions are as distinct as he would make us suppose.

First Stage: The vomiting immediately follows the swallowing of food and there are attacks even when the stomach is empty, the ejected mucus and bile often being streaked with blood. There are epigastric pain and tenderness on pressure over the region of the stomach. Emaciation soon becomes evident, associated with increasing weakness; ptyalism and diarrhœa may appear as complications.

Second Stage: In this stage there may be an elevation of temperature caused by auto-intoxication, but more serious is the rapid and weak pulse ranging from 120 to 140. The general condition of the patient is very bad: the skin is dry, the face is emaciated, and the eyes are sunken; sordes appear on the teeth and the breath has an offensive odor; the mouth and throat are dry. The urine is scanty in amount and of high specific gravity and fœtid odor; it may contain albumin and casts. The increasing weakness of the patient is apparent in the attacks of syncope, so that she is obliged to remain in bed.

Third Stage: In this stage the vomiting ceases and there is the advent of nervous symptoms such as disturbances of vision, delirium, and hallucination; coma usually precedes death.

Pinard has pointed out that in cases of pernicious vomiting the nervous symptoms may be detected in the early stage, and that Dubois drew his conclusions regarding the febrile stage from the pulse and not from the thermometer, as that instrument was not used in medicine at the time he wrote. All of the cases do not end fatally, but the physician must not be deceived by the sudden remissions which occur even in the most serious cases and which do not indicate any permanent improvement.

The pathologic lesions are variable and more often indicate that pregnancy has supervened upon some diseased condition than that gestation is a direct cause; frequently there is no demonstrable lesion at all. Such conditions as disease of the decidua and cervix, tumors of the uterus and ovaries are looked upon by Pinard as accidental accompaniments in those cases in which such lesions are present.

Causation.—The two important elements in the vomiting of pregnancy are the condition of the nervous system and reflex stimulation. The impressionable state of the nerve centres which is a feature of beginning gestation, may permit the growing uterus to have a more profound effect during early pregnancy than later when nervous equilibrium is attained; or, the reflex from the pelvis may be heightened by the existence of some abnormality, such as a displacement, laceration, inflammation of the cervix, or new growth. Such conditions as these may account for the *simple vomiting* of pregnancy, but for the explanation of hyperemesis they are not fully satisfactory. Pinard considers that hyperemesis is a part of the symptomatology of auto-intoxication and it seems reasonable to suppose that toxins circulating in the blood may be the sole causes except in such cases in which their action is reinforced by some abnormal stimulus coming from the pelvis. It is a striking fact that even the simple form of vomiting is absent or slightly marked in those women whose excretions are naturally sufficient, or have been made so by appropriate treatment.

Prognosis.—The disease is serious in the first stage, more so in the second, and almost always fatal in the third. Death of the fœtus, or abortion improves the outlook for the patient. Gueniot found that in 118 patients recovery took place in 72 and 46 died; of the 72 who recovered, 42 either spontaneously aborted or else abortion or premature labor was induced. Of the 46 who died, 28 did not abort, and 18 had abortion or premature labor induced, or miscarriage was spontaneous.

Diagnosis.—In a case of severe vomiting the question of pregnancy must first be established and then it must be decided whether or not the gastric disturbance is due to some intercurrent or pre-existing affection. If the case undoubtedly is hyperemesis of gestation the stage of the disease must be determined.

Treatment.—Every case of simple vomiting calls for investigation, as the physician cannot know whether or not it is the beginning of serious disturbance. The adoption of Pinard's theory of hepato-toxæmia entails the examination of the urinary excretion and those medicinal, dietetic, and hygienic measures described under the heading of toxæmia. Large doses of chloral and sodium bromide per rectum may diminish the reflex action of the centres after the toxæmia has been overcome; in this same connection may be mentioned such measures as spinal douches and blisters or stimulating liniments applied over the region of the fourth and fifth dorsal vertebræ.

The local treatment consists in the correction of any abnormality discovered in the pelvis. Dilatation of the cervical canal, by means of the steel branching dilators, has been performed with the idea that some cicatricial contraction of the cervix might originate the reflex irritation. Moreau and Grailly Hewitt consider uterine displacements to be the most frequent causes of irritation; of course if any malposition of the uterus be discovered it should be corrected. Inflammation of the vagina or cervix should receive appropriate local treatment, but no local applications nor manipulation must pass the internal os and strict asepsis must be observed.

In those cases in which vomiting has continued for some time the stomach becomes so irritable that complete rest must be given it, therefore rectal feeding may be employed to advantage. The long list of drugs which are advised as gastric sedatives is an evidence of the unsatisfactory results obtained before the mechanism of the disorder was understood; the list comprises all those drugs mentioned in the text-books on general medicine for treatment of stomach diseases.

If, in spite of treatment addressed to local and general conditions, the hyperemesis continues, artificial abortion is the last resort and it is wise to adopt this measure before the patient has advanced so far in the second stage of the disease that the shock of the operation uses up her remaining strength.

Ptyalism.—When this affection develops it usually begins early in gestation and lasts until the fourth or fifth month. The discharge of saliva may be so profuse that the patient is obliged to wear a napkin or use a cup for the reception of the secretion which may amount to as much as three quarts in the twenty-four hours.

The cause of the disease is not clear; in some cases it seems to be merely sympathetic; in others there is auto-intoxication, the poison acting upon and being eliminated through the salivary glands.

The treatment of ptyalism is unsatisfactory, except when it is relieved by overcoming the toxæmia. Benefit is sometimes derived from the use of astringent mouth-washes, by the administration of tincture of belladonna or pilocarpine, and by the application of a weak galvanic current to the glands.

Dental Caries.—There is a popular saying that each pregnancy costs the woman a tooth, and it certainly is a fact that gravid women are apt to suffer from dental caries, due either to alteration in the buccal secretions or to the demand on the part of the fœtus for lime salts. At the beginning of gestation the woman should have her teeth put in order, but all extensive or painful operating should be postponed until after delivery on account of the nervous irritation. Temporary fillings, the use of dental floss and antiseptic mouth washes after meals, and the administration of syrup of lactophosphate of lime will do much to preserve the teeth during the term of gestation.

Gingivitis.—During gestation the gums may become red, swollen, and bleed easily. The disturbance comes on about the fourth month and may not disappear for one or two months after confinement. The treatment consists in keeping the mouth clean and disinfected by the use of a solution of chlorate of potassium and applying tincture of iodine to the gums.

Constipation and Diarrhœa.—On account of the pressure of the growing uterus the majority of pregnant women suffer from constipation which is a potent element in the production of toxæmia. Furthermore the loaded rectum tends to promote pelvic congestion and develop hemorrhoids. There is nothing peculiar about the treatment of constipation during pregnancy, except to utter a warning against the use of irritant cathartics which sometimes will produce uterine contractions. In a limited number of cases the patient suffers from diarrhœa instead of from constipation and under such circumstances the physician should investigate the case with the view of discovering a possible toxæmia of which the diarrhœa is but a symptom.

Disorders of the Circulatory System.—Attacks of palpitation and syncope are not uncommon during gestation and are apt to occur in nervous, anæmic women from a number of reflex causes. In the last few months of pregnancy, especially when there is overdistention of the uterus, the pressure of the fundus against the diaphragm may be the cause of the disturbance. The treatment is the same as in the non-pregnant.

Hemorrhoids and Varices.—Hemorrhoids may become very troublesome during the latter half of pregnancy, and varices of the legs or vulva, accompanied by more or less œdema, may be present. As the cause is the pressure of the gravid uterus interfering with the return flow through the veins, treatment should be palliative. Constipation should be prevented, elastic bandages applied to the lower extremities, and the patient kept in the recumbent position as much as is feasible. There is some danger of rupture of enlarged veins in the leg or vulva, so the patient should be taught how to apply a pad in order to control the hemorrhage pending the arrival of the physician.

Anæmia.—Unless the blood hypertrophies to meet the demands of the pregnant state the woman will suffer from anæmia. Many women are temporarily anæmic during the early months until the richness of the blood is established. If the blood remains impoverished, or becomes so, the usual symptoms of anæmia appear and there are a few cases on record in which the disease took the pernicious form. The routine treatment by diet, oxygen, iron, and arsenic is indicated, and in grave cases it may be necessary to bring the pregnancy to an end.

Disorders of Respiration.—Cough and dyspnœa sometimes are troublesome to the pregnant woman and the cause may be reflex or mechanical. For those cases of sympathetic origin valerian and bromides are useful, but the mechanical element cannot be removed until the end of pregnancy, although the patient may get some relief by avoiding exertion and wearing extremely loose clothing.

Disorders of the Nervous System.—Neuralgia.—The pregnant woman often suffers from attacks of neuralgia in various parts of the body. The growing uterus may press upon the pelvic nerves, especially if there be inflamatory deposits around the uterus. In other cases the pain is due to constipation which permits hardened fæces to act as irritants or produces toxæmia. In primiparæ, during the latter months, the distention of the abdominal tissues may cause suffering. The face and breasts are regions often affected.

The treatment consists in removal of the cause whenever possible: irrigations of the bowels will remove the hardened fæces and elevation of the fundus will relieve the pressure upon the pelvic nerves. In facial neuralgia the teeth should be examined for caries. The general treatment lies in overcoming toxæmia, in administering iron and arsenic as well as employing the usual hygienic means for the cure of anæmia. For the relief of pain the coal-tar products should be preferred to opium or morphine.

Herpes.—This is one of the most unpleasant nervous disorders to which the pregnant woman is liable, but fortunately it is not very common. The disease usually has appeared between the third and fifth months and in certain patients has recurred in successive pregnancies. The disorder presents no peculiarities during gestation nor does it seem to affect its course. Herpes is included among the various manifestations of toxæmia.

The treatment consists in attention to general hygienic conditions together with the administration of hypophosphates, arsenic, and iron. As local applications carbolized vaseline, dusting powders, and soothing lotions are recommended.

The Mental Disturbances of Gestation.—It is stated that eight per cent. of the cases of insanity among women originate during pregnancy, labor, or the lying-in-period, and we can understand how such may be the case when we recall the frequent alterations in the mental characteristics of gravid patients. Mental disorder is less apt to develop during pregnancy than during or subsequent to labor, but the peculiar irritability or depression present during gestation may be but the prodromal symptoms of marked melancholia with suicidal tendencies. In some cases there is merely mental confusion or stupor, and mania is much less common than melancholia. Occasionally, instead of depression, there is mental exaltation and the patient becomes very talkative, showing great activity both of body and mind.

Heredity is an important predisposing factor in the insanity of pregnancy and renders the patient extremely susceptible to such influences as toxæmia, fear of the approaching confinement, or remorse for an illegitimate conception.

The prognosis is not so bad as among the non-pregnant. In 19 cases collected by Marcé the results were as follows:

Cured after delivery	7
Worse after delivery	1
Cured during pregnancy	2
Became chronic	9

The insanity is said to have no effect upon the course of the pregnancy, although in five cases out of eleven Marcé reports the children as born dead or dying shortly after delivery.

The prophylactic treatment is very important; the physician should recognize the signs of irritability and depression and see that, as far as possible, all disturbing influences are eliminated. At the same time he should impress upon the family the necessity for constant watchfulness and anticipate any attempt at suicide. The insanity itself is managed by maintaining the patient in peaceful surroundings, by attention to the nourishment and excretions, by the use of sedatives and those drugs employed for the relief of anæmic conditions.

Œdema during Gestation.—In the last two or three months it is not uncommon for the pregnant woman to suffer from œdema of the lower extremities and vulva, associated with albuminuria, increased intra-abdominal pressure, and varicosities. Pinard has called attention to a more or less generalized form of œdema which he considers to be due to toxæmia and in which such causes as pressure, varices, and renal disturbance are absent. Stolz designated this œdema as *serous cachexia;* the infiltration of the tissues may be quite as well marked in the abdominal wall above the symphysis as in the lower extremities; in rare instances there is effusion into the serous cavities of the body.

The treatment consists in regulating the elimination, rest in bed, and a milk diet, together with the administration of iron and arsenic. In severe rebellious cases puncture of the labia may be necessary, but it is to be remembered that there is some danger of stimulating uterine contractions and that the low vitality of the tissues predisposes to gangrene and infection. The use of the trocar may be required to evacuate fluid from the chest or abdomen.

Disorders of the Genital Apparatus.—Pruritus Vulvæ.—Some gravid women suffer from an intolerable itching of the vulva and the constant scratching soon produces local lesions which intensify the irritation. The causes of the pruritus are either the local action of vaginal discharges or an irritable condition of the nerves or both combined. In bad cases the woman is prevented from sleeping and the constant torture brings about deterioration of the general health. Treatment lies in the use of warm vaginal irrigations, together with hot sitz-baths and the application of soothing lotions. A tampon of absorbent cotton introduced within the vagina and frequently changed will prevent the discharge from reaching the external parts. When the nervous element is prominent, tonic and general hygienic measures are indicated in combination with the local applications.

Vegetations upon the Vulva.—The increased vascularity of pregnancy stimulates the growth of warty masses upon and around the vulva. These growths may become as large as the fœtal head; they are of a rosy or livid color and, except upon the surface, are moist and exude a foul discharge. These so-called *venereal warts* or *condylomata acuminata* are often associated with a gonorrhœal inflammation, but there are cases in which no venereal element seems to be present, the cause being dependent upon pregnancy alone. Sometimes the tumors are sources of obstruction to the delivery of the fœtal head.

Treatment.—The extreme vascularity of the parts makes the removal of the masses during pregnancy rather a dangerous operation and also exposes the patient to the risks of abortion. When possible the treatment during gestation should be palliative by the application of antiseptic washes or astringent dusting powders. Successive portions of the growths may be touched with a glass rod dipped in nitric or pure carbolic acid. After the confinement the warts may spontaneously disappear or their vascularity be so lessened that surgical treatment is a simple matter.

Displacements of the Pregnant Uterus.—The gravid uterus may be found displaced forward, backward, sideways, or downward. The most frequent uterine displacement complicating pregnancy is retroversion.

Retroversion.—In 24,000 cases of pregnancy Martin found retroversion or retroflexion 121 times. The cause of the displacement usually antedates the pregnancy, except in those cases of acute dislocation of the organ from a fall or blow, and from the muscular exertions of lifting, vomiting, or defecating. When pregnancy develops in a retroverted uterus the organ usually becomes elevated as the increase in size takes place and, by the fifth month, is too large to occupy a posterior position. Certain conditions, however, may hinder the elevation of the fundus: the uterus may be adherent and unable to break away; an over-prominent sacral promontory may not give sufficient space for the fundus to swing upward; a tumor in the posterior uterine wall, or one superimposed, may imprison the organ. No doubt retention of urine, with the consequent distention of the bladder, is a mechanical hindrance at times. If the uterus is unable to rise above the pelvic brim either abortion takes place or the symptoms of *incarceration* show themselves. There are two varieties of incarceration, *complete* and *partial:* in the complete form the entire organ is held beneath the pelvic brim; in the partial the uterus becomes sacculated, a portion, made up of the posterior wall, remains in the pelvis, while the fœtus develops in the anterior free portion.

Symptoms.—Symptoms rarely appear before the third nor after the fifth month; after the latter date the uterus is too large to become retroverted and before the third it is too small to give rise to signs of compression. At first, owing to the increased weight of the gravid womb, the symptoms are merely an intensification of the common signs of backward displacement. There are backache, dragging sensations, feeling of weight in the pelvis, irritation of the bladder and rectum, and, at the same time, there may be considerable difficulty in emptying those reservoirs. When the displacement occurs suddenly there are no prodromal symptoms; the patient experiences a sudden pain in the lower abdomen followed by signs of pressure. After the incarceration has developed the prominent symptoms come from the urinary organs. The cervix presses upon the urethra and a cystitis results which may pass into a gangrenous form, the urine becoming foul and containing pus, blood, and broken-down tissue. The patient may have chills and fever, and the infection ascend to the kidney, causing death by uræmia. In some cases the bladder cannot empty itself and rupture occurs. If the incarceration continues the pelvic pain becomes very intense and the uterine wall may become gangrenous, leading to a termination of the case through septic peritonitis. In rare cases the fundus has been expelled through a ruptured vaginal wall and perineum.

Prognosis.—In retroversion of the pregnant uterus the prognosis is very serious unless the condition relieves itself or is promptly treated. Unless abortion occurs incarceration is always fatal if left to itself. Gottschalk's statistics, based upon 67 fatal cases of backward displacement, give the causes of death as follows: uræmia and collapse, 16; septicæmia from the bladder, 4; gangrene of the bladder, 3; rupture of the bladder, 11; peritonitis from injury of the bladder, 17. The other causes of death were peritonitis, pyæmia, and gangrene of the intestine. These figures illustrate the frequency with which the urinary organs are involved.

Diagnosis.—In addition to the presence of pressure symptoms there are certain important physical signs. On digital examination the finger detects an elastic rounded body lying in Douglas' pouch and filling more or less of the pelvic cavity; the cervix may be hard to reach or found directly behind the symphysis, the external os looking upward in cases of retroversion or more or less downward in flexion. On feeling above the pubes the fundus of the uterus is missing from its normal position and its place may be occupied by a cystic tumor formed by the distended bladder unless catheterization has been performed in advance. Per rectum more of the tumor is accessible to the finger. A retroversion must be differentiated from all those tumors which may lie in Douglas' pouch, such as an ovarian cyst, ectopic gestation, or a fibroid; a combination of tumor and normal pregnancy is particularly difficult to diagnosticate unless an anæsthetic be administered.

Treatment.—As soon as retroversion of the gravid uterus is discovered efforts at reposition must be made. The woman should be placed in the knee-chest position, a Sims speculum introduced, and the fundus pushed upward while the cervix is drawn down by means of a tenaculum; sometimes the upward pressure can be made to better advantage through the rectum. In difficult cases an anæsthetic should be administered, the patient put in the lithotomy position, and, by means of bimanual manipulation, the fundus swung *around* the promontory to the front. As soon as the uterus is in proper position tampons or a pessary must be employed until its growth has rendered it too large to enter the pelvis again. When adhesions exist three courses of treatment are at the disposal of the physician: 1. Repeated tamponade of the vagina with cotton or wool soaked in boroglyceride and ichthyol with the hope of causing gradual absorption of the restraining bands and elevation of the fundus. This method of treatment can be carried out only in those cases in which there are as yet no urgent symptoms. 2. Posterior vaginal section followed by manual separation of the adhesions and replacement of the uterus. 3. Abdominal section and manual replacement.

The choice of methods will depend upon the urgency of the case. When incarceration has developed attention must first be paid to the bladder, and if careful attempts at catheterization fail the urine must be evacuated through a suprapubic puncture. If manipulations through the vagina fail the abdomen should be opened and the fundus lifted into position. Abdominal section for the relief of incarceration has been performed twice by M. D. Mann, twice by Mouchet, and eleven times by Jacops; all the cases were successful except one of Jacops' which aborted. Artificial abortion needs to be performed but very seldom and the difficulties and dangers of emptying and draining the incarcerated uterus are much greater than those connected with the intra-abdominal method of treatment if the case is in skilled hands. Vaginal hysterectomy would be proper for those cases in which the uterine walls have become inflamed and damaged by the compression.

Anterior Displacements of the Pregnant Uterus.—These may occur in the first or last part of pregnancy. When the ovum develops in an anteflexed uterus usually the fundus elevates itself without trouble unless the uterus is bound down by inflammatory deposits, pressure from above, or the operation of ventral fixation has been performed. If the organ does not right itself there are more or less pain and disturbance of the bladder followed by abortion.

The diagnosis is made by bimanual examination, and treatment consists in elevating the fundus by the use of tampons and massage. If the uterus is fixed on account of adhesions or previous operation abdominal section would be justifiable. In the latter months of gestation an anteversion may take place from weakness of the abdominal muscles and especially from a separation of the recti. Multiparity, contracted pelvis, lumbar lordosis, and excessive distention of the uterus are all predisposing causes.

The symptoms are marked when the patient is upon her feet; she experiences discomfort and difficulty in locomotion. When the patient is standing or sitting the uterine tumor is very prominent, the fundus may incline directly forward and the external os look backward; in exaggerated cases the uterus is inverted so that its anterior surface rests against the thighs. On external palpation the fœtal parts may be easily felt, as the uterus is covered only by a layer of skin and peritoneum. The cervix may be inaccessible unless the entire hand be introduced within the vagina. In the dorsal position both the signs and symptoms disappear.

The treatment is to keep the patient upon her back as much as possible and order her to wear a well-fitting abdominal supporter. During the last weeks of gestation it is important to keep the uterus in the correct axis of the superior strait so as to insure proper engagement of the presenting part.

Prolapse of the Pregnant Uterus.—This displacement is an uncommon complication of pregnancy. The increase in weight is likely to produce a recurrence in those patients who already have suffered from this form of uterine dislocation; in rare instances blows, falls, or strains have produced a sudden descent of a uterus which heretofore occupied its normal position. As pregnancy advances usually the prolapsed organ becomes spontaneously replaced, but if such be not the case either abortion takes place or the symptoms of incarceration appear. A few authors claim that it is possible for gestation to go to term in a uterus prolapsed between the thighs of the patient.

The treatment consists in replacing and retaining the organ until danger of repetition of the displacement is prevented by the size of the uterus. If replacement is impossible and there are signs of incarceration abortion should be induced; removal of the uterus is justifiable in septic cases.

Lateral Displacement of the Pregnant Uterus.—Pathologic lateral deviations of the uterus are rare during gestation, the inclination of the fundus to the right being regarded as physiologic. Excessive lateral flexion will produce symptoms of pressure, such as œdema and pain in the leg corresponding to the side toward which the axis inclines. The chief importance of lateral deviations is their influence in producing faulty presentations or positions at the time of labor.

Relaxation of the Pelvic Joints.—In certain cases the physiologic softening of the interarticular cartilages is carried to excess and an abnormal amount of movement in the joints is permitted. The symptoms come on during the last two months of gestation and consist of pain in the region of the symphysis, groin, and lumbar region; walking becomes difficult or impossible both on account of the pain and from the effort required to maintain the proper balance of the body. Pressure over the symphysis is painful. The patient should be examined in the standing posture by introducing a finger into the vagina and pressing against the inner surface of the symphysis while the patient supports her weight first upon one leg and then upon the other; in this way the movement in the joint will be appreciable to the examining finger. The same result will be attained when the woman is lying down, by directing her to flex the thighs alternately.

Treatment.—During pregnancy a snug bandage about the pelvis will give some relief, except in bad cases when the patient must remain in bed. General tonics are sometimes beneficial. The condition usually cures itself in a month or two after labor, and during the interval a harness to immobilize the pelvis should be worn.

Traumatism and Surgical Operations during Gestation.—There are instances in which a gravid woman has suffered from severe injuries without interruption of the pregnancy and yet sometimes trifling accidents will cause abortion. The irritability of the uterus, the seat of the injury, and the amount of blood lost are important factors in affecting the result. According to Cohnstein penetrating wounds of the abdomen, without injury to the uterus, are apt to arrest gestation; but Harris has reported a case in which the abdomen of the woman, six months pregnant, was lacerated by the horn of a bull so that the omentum and intestines protruded, yet the pregnancy went to term. The existence of pregnancy seems to have no influence upon the healing of wounds, although there is evidence that the gravid state may cause retardation in the union of fractures.

Major surgical operations, such as amputation at the hip-joint, the removal of ovarian tumors and even fibroids from the uterus, do not necessarily interrupt the pregnancy. Sir James Paget summed the matter up by saying that it would be mere recklessness to operate upon a pregnant woman without good cause; yet, if good cause exists, she may be treated very successfully. Operations upon the rectum seem to be particularly dangerous as regards the risk of inducing abortion and, to a less extent, do those upon the vulva. Pregnancy is not a contraindication to removal of the breast for cancer. When fixing the date of an operation upon a gravid woman the time of the menstrual epoch should be avoided, and in all cases particular care should be taken to diminish shock and hemorrhage.

Hernia of the Pregnant Uterus.—The gravid uterus is very rarely found occupying the inguinal canal, and when such is the case the ovum usually is in one horn of a uterus bicornis. In the *Arch. f. klin. Chir.*, xlix., 4, W. Rosanoff has reported a case of inguinal hernia of the gravid uterus in which the tumor reached almost to the knee; its largest circumference measured 80 cm. After delivery he reduced the uterus into the abdominal cavity, the left ovary and a part of the left tube remaining in the canal until an operation for radical cure was performed. Rosanoff considered that in the beginning the canal was occupied by the ovary, left tube, and coils of intestine, the uterus gradually following.

Montgomery A. Crockett.

GETTYSBURG SPRINGS.—Adams County, Pennsylvania.

Post-Office.—Gettysburg. Hotels. Gettysburg is reached by the Philadelphia and Reading and by the Western Maryland Railroads (separate depots). The springs are easily accessible by street car or omnibus. Two prominent springs, known as the Gettysburg "Katalysine" and the Gettysburg "Lithia" Springs, are reported by the Government Geological Survey. The following remarks refer to the former, as we have not been able to gain any recent information concerning the Lithia springs. The Katalysine Springs are located in a picturesque valley a short distance west of the town. It is said that the great battle of Gettysburg began in the immediate vicinity (Walton). The following analysis of the Katalysine water was made by Professor Genth, of Philadelphia:

One United States Gallon Contains:

Solids.	Grains.
Sodium carbonate	0.22
Magnesium carbonate	.33
Iron carbonate	.02
Manganese carbonate	Trace.
Calcium carbonate	5.02
Sodium chloride	.66
Lithium chloride	Trace.
Potassium sulphate	.21
Sodium sulphate	.25
Magnesium sulphate	6.78
Calcium sulphate	.83
Calcium phosphate	Trace.
Calcium fluoride	Trace.
Magnesium borate	.03
Silicic acid	.20
Organic matter, with trace of nitric acid, etc	.70
Impurities suspended in water, like clay, etc	1.10
Total	16.35

In addition, traces of carbonate of copper, sulphate of strontium, alumina, carbonate of nickel, carbonate of cobalt, and sulphate of baryta have been found. This water is said to be efficient in gout and rheumatism, and has proved of value in gravel, catarrh of the stomach, and dyspepsia. The combination of an alkali with the salts of lime, as observed in this spring, is a very valuable one. The water is used commercially.

James K. Crook.

GEUDA SPRINGS.—Cowley County, Kansas.

Post-Office.—Geuda Springs. Hotel and boarding-houses.

The Geuda Mineral Springs are located on the St. Louis and San Francisco Railroad, one mile distant from the Arkansas River and eight miles north of Indian Territory. The town of Geuda Springs, which has about 800 inhabitants and is rapidly growing, is pleasantly situated at the edge of a beautiful and undulating plateau, which is everywhere dotted with fine farms and neat farm-houses. The elevation above the sea is about 1,400 feet, and the atmosphere is pure and wholesome. The winters are short and open, making constant outdoor exercise possible. There are very few hot days in the summer, the thermometer rarely extending above 100° F., but, as a rule, the days are balmy and the nights cool and refreshing. The springs are seven in number, and bubble up in a space less than twenty feet square. Near the springs is a beautiful lake of salt water, with an area extending to the westward nearly two miles, and another to the southward nearly half that distance. The evaporation of the water causes the beach to be covered with pure, crystallizable salt. This picturesque body of salt water, constantly fed by salt springs, furnishes fine advantages for bathing. The lake bottom is hard and sandy, and bathers can secure any depth of water desired. A commodious bath-house in connection with the springs affords opportunities for any variety of bath which may be desired. Following is a detailed analysis of the seven springs by Professor Bailey, of the Kansas State University:

NUMBER OF GRAINS IN EACH UNITED STATES GALLON OF 231 CUBIC INCHES.

	Spring No. 1.	Spring No. 2.	Spring No. 3.	Spring No. 4.	Spring No. 5.	Spring No. 6.	Spring No. 7.
Sodium chloride....	1030.93	1056.28	815.68	671.76	357.05	432.20	504.21
Calcium sulphate...	199.64	204.73	167.58	158.29	145.88	147.33	160.17
Magnesium sulphate	25.56	24.24	28.53	26.64	24.98	27.43	22.86
Magnesium chloride	16.55	19.96	10.01	7.90	8.45	4.95	9.66
Calcium bicarbonate	3.70	5.90	5.99	6.86	10.67	12.50	5.51
Potassium sulphate..	12.12	1.69	1.90	1.90	.82	.54	.47
Sodium phosphate..	.02	.02	.02	.02	.04	.08	.08
Sodium bromide....	.02	.02	.01	Trace			
Sodium iodide......	Trace	.....	Trace				
Sodium biborate....	.16	.16	.16	.08	.12	.12	.25
Sodium nitrite......	.38	.40	.18	....	.02	.03	.03
Sodium bicarbonate.	.41	.32	.39	.69	.49	.31	.60
Sodium sulphide....	.....	.....	.....	....	....	.65	
Lithium chloride....	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Iron bicarbonate....	.07	.19	.07	.05	.03	.06	.08
Alumina...........	.06	.01	.....	.01	.01	....	.01
Silica.............	.67	.86	.81	.79	.92	.73	.79
Organic matter.....	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Total..........	1280.29	1314.78	1031.14	874.99	549.48	626.92	704.72
Free carbonic acid gas in cubic in....	34.96	27.69	18.32	17.64	23.98	22.16	29.05
Sulphureted hydrogen gas..	.....	.....	.....	....	....	Trace	Trace
Specific gravity.....	1.018	1.016	1.013	1.012	1.008	1.009	1.009
Temperature........	63° F.	63° F.	63° F.	63° F.	63° F.	63° F.	63° F.

These waters may be classed as belonging to the muriated and sulphated-saline variety (carbonated). They have found their most suitable application in liver, kidney, and stomach disorders, general debility, anæmia, and rheumatism. Some of the springs have gained considerable celebrity in the local treatment of conjunctivitis, indolent ulcers, leucorrhœa, etc.

James K. Crook.

GEUM. See *Avens.*

GIANT CELLS.—These are very large cells of mesenchymal origin, often many times as large as other cells with which they are associated. They frequently have many nuclei—sometimes as many as two hundred,—or a single nucleus which may be deeply lobulated or "beaded," that is, broken up into a number of portions connected by threads of nuclear material. But the giant cell is sometimes distinctly mononuclear and on the other hand there are in the body many polynuclear cells, such as the ordinary polymorphonuclear leucocytes and the striated muscle fibres, which cannot be classed as giant cells. Therefore the important point in the definition is the size rather than the number of nuclei.

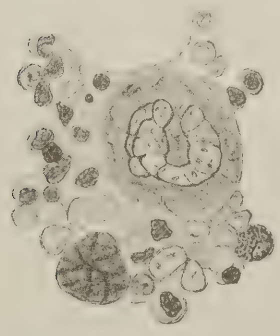

FIG. 2294.—Bone Marrow, Showing Giant Cells. × 830.

As to their origin, it is not probable, as has been believed, that they ever arise by the fusion of small mononuclear cells. Occasionally, under artificial conditions, cells without cell walls may fuse, but the formation of a true syncytium is rare and the appearance is generally due to faulty technique (Henneguy). It is more probable that each giant cell begins as a single mesenchymal cell in which growth continues while the process of division fails or is not completed. Nuclear division, when it occurs, usually follows the direct or amitotic method, though the indirect or karyokinetic may be seen. Nedjelsky, who studied chiefly cell division in malignant growths, describes different varieties of amitosis in which the separation, partial or complete, usually began in the nucleolus, and later often failed to involve the rest of the nucleus or the protoplasm. A multinuclear giant cell may subsequently divide into a number of small mononuclear cells.

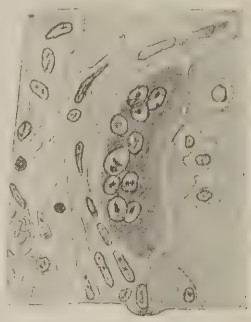

FIG. 2295.—From Section of Snout of Embryo Pig, Showing Osteoclast. × 410.

Without attempting to ascribe a common function to all giant cells we may safely assert that there is often evidence of phagocytosis. Thus in tuberculosis the giant cells often contain bacilli; in tumors degenerating elastic fibres may be seen in them; and in the case of the osteoclasts they undoubtedly play an important part in the removal of lime salts in developing and growing bone. Phagocytosis is even more clearly seen in the giant cells which are found in the neighborhood of foreign bodies.

Giant cells occur most commonly in connection with reticular and related tissues and in the blood-forming organs. Normally they are perhaps most familiar in marrow. Here, away from the bone, are large giant cells with partially divided and irregularly lobulated nuclei, and also large masses of nuclear matter having an obscurely reticulated structure and not appearing to be surrounded by protoplasmic bodies. Close to the bone are osteoclasts, large cells with few or many nuclei, apparently completely divided. They lie in shallow excavations in the bone, Howship's lacunæ. Their action leads to the destruction or dissolution of the adjacent calcareous matrix.

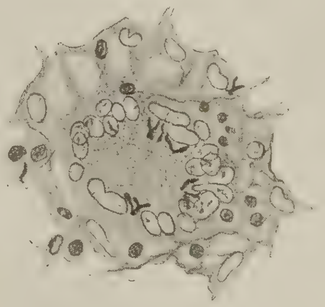

FIG. 2296.—Portion of a Tubercle, Showing a Giant Cell Containing Bacilli. × 410.

In the spleen we can recognize large mononuclear cells, in which the presence of red corpuscles suggests phagocytosis. These cannot properly be called giant cells; but in the young of many animals and in the embryo the spleen contains larger cells with lobulated nuclei (megacaryocytes)—not as a rule to be found in the adult. Giant cells are also described as occurring in hæmolymph glands and in the embryonic liver.

Pathologically, giant cells are more widely distributed. They arise from fixed tissue cells of the diseased part, connective-tissue cells, or endothelial cells of blood and lymph capillaries—not, as some have believed, from leucocytes. Multinucleated forms are seen in hyperplastic and regenerative growth of connective tissue. They occur in tumors, especially in sarcomata originating in the marrow or periosteum. Large polynuclear forms may also be seen in the vicinity of foreign bodies, which they enclose in their protoplasm if small, and whose dissolution they otherwise tend to bring about.

Perhaps their most familiar occurrence is in tuberculosis. Here, though not always present, they are often large and prominent and are important landmarks in the identification of the disease. They occupy the centres of miliary tubercles. Their nuclei are very numerous, completely divided and commonly arranged about the border of the cell or gathered into unequal or irregular groups at the poles. They often have protoplasmic processes, whose relation to the reticulum is not at present clear. They may have necrotic centres and contain tubercle bacilli. *Ralph C. Larrabee.*

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Marchand: Virchow's Archiv, Bd. xciii., p. 518.
Nedjelsky: Beitr. z. path. Anat. u. z. allg. Path., 1900, Bd. xxvii.
Rona: Beitr. z. path. Anat. u. z. allg. Path., 1900, Bd. xxvii.
Warthin: Journal of Medical Research, July, 1901.
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GIGANTISM. See *Acromegaly*, and *Hand and Fingers, etc.*

GILROY HOT SPRINGS.—Santa Clara County, California.

Post-Office.—Gilroy Springs. Hotel. These springs are located on the Coyote River, nine miles northeast of the town of Gilroy, in the Santa Clara Mountains. They are reached by the Southern Pacific Railroad to Gilroy, and from thence by stage over a picturesque mountain road. The springs lie nestled in among the mountains, surrounded by fragrant forests of spruce and pine. The atmosphere is rich in ozone, and the climate very genial. There is one main spring, which flows in great abundance. The temperature of the water varies from 108° to 115° F. Anderson's analysis:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	31.75
Sodium carbonate	1.42
Sodium sulphate	.75
Potassium iodide	Trace.
Potassium sulphate	2.16
Magnesium carbonate	2.45
Magnesium sulphate	9.04
Calcium chloride	8.50
Calcium sulphate	2.70
Ferrous carbonate	.26
Ferrous oxide	Trace.
Arsenic	Trace.
Silica	3.31
Organic matter	.52
Total solids	62.86
Gases.	**Cubic Inches.**
Free carbonic acid gas	12.17
Free sulphureted hydrogen	9.25

The analysis shows a light alkaline-sulphureted water. It is used with considerable benefit in syphilis, rheumatism, and tuberculosis, in glandular swellings, in chronic skin eruptions, etc. The water is also used for bathing, for which excellent facilities have been constructed. *James K. Crook.*

GINGER.—Zingiber. The rhizome of *Zingiber Zingiber* (L.) Rusby (*Z. officinale* Roscoe, U. S. P.) (fam. *Zingiberaceæ*). This plant belongs to a remarkable order of tropical perennial herbs with horizontal, fleshy, often lobed and branched rhizomes, more or less developed upright stems, with two-ranked, alternate, parallel-nerved, sheathing leaves, and, theoretically, trimerous, irregular flowers in various clusters.

The flowers vary greatly in color, from nearly white to a purplish-blue. The richer the soil, the better the ginger, and the product of newly cleared land holds a special place in commerce. It is probably a native of Southern Asia, but is not known wild, having been cultivated for many hundred years. It has also been transplanted to tropical Africa and the West Indies, besides many other places, where it is extensively cultivated.

It has been used as a spice, even in Europe, almost since the beginning of this era, having been imported from the East by way of the Red Sea. The plant was carried to the West Indies soon after the discovery of the New World, and a few years later ginger was exported from St. Domingo back to Europe.

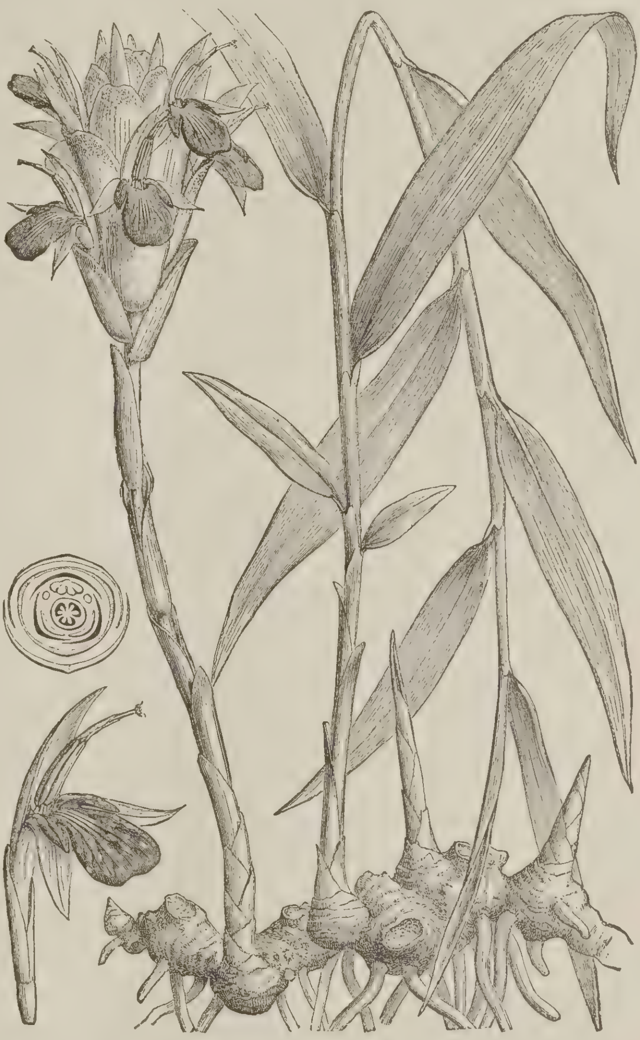

Fig. 2297.—Ginger Plant about One-third Natural Size. (Baillon.)

Description.—Ginger is either coated, that is, simply washed and dried without removing the cuticle, or else scraped, when the outer surface is peeled or scraped away. When the bark is stripped from the two flat sides, it is known as "half-coated." It is in pieces technically called "hands," "about three-fifths of an inch broad, flattish on one side, lobed or clavately branched; deprived of the corky layer (peeled ginger), pale buff-colored, striate, breaking with a mealy, rather fibrous fracture, showing numerous small, scattered resin cells and fibrovascular bundles, the latter enclosed by a nucleus sheath; agreeably aromatic, and of a pungent, warm taste." When ginger is not peeled it has a grayish or brownish wrinkled surface. Inferior and dark-colored grades are sometimes bleached with sulphur, chlorinated lime, etc., or are even "whitewashed" with chalk and water, or some such mixture, to give them a whiter and more salable appearance. This treatment also protects them against the attacks of insects. The relative commercial and medicinal values of ginger do not agree. For medicinal purposes it is better with the very active rind left upon it, but its commercial value depends more upon its ability to yield a clear, light-colored preparation, which is true of the peeled articles. The principal varieties in the order of their estimation are Jamaica, Cochin, and African. The last, though the cheapest, contains the largest amount of active constituents, and is to be preferred for medicinal use.

Composition.—Ginger contains a pale yellow *volatile oil* to the extent of about one or two per cent., having its odor and taste without its pungency. The remaining constituents are a composite *resin*, besides the real source of its pungency, *gingerol*, which, however, is not volatile or aromatic. Twenty per cent. of starch, fat, gum, and various amorphous and uninteresting substances make up the rest. The oil and resins are contained in cells resembling those of the parenchyma, and irregularly scattered among them. The ethereal extract (*Oleoresina Zingiberis*, U. S. P.) is composed of these resins in combination with the essential oil, fat, etc., and is yielded by different varieties to the extent of five to ten per cent.

Action and Use.—Ginger is a spice more aromatic and less pungent than pepper, and, like others of its class, in suitable dose is gently stimulating to the stomach and intestines, and in its way a carminative tonic. In large doses it is irritating; locally applied to the skin it is rubefacient to a less degree than mustard, and useful where a mild counter-irritation is desired. It is used in colics, atonic dyspepsia, flatulence, etc., and is a favorite flavor for cakes, drinks, and preserves.

Administration.—In powder the dose may be taken as from 0.5 gm. to 1 gm., usually mixed with other aromatics. An infusion, under the name of "ginger tea," is a favorite preparation in the country. A fluid extract is official (*Extractum Zingiberis Fluidum*, U. S. P.), but not much used. The tincture (*Tinctura Zingiberis*, U. S. P.) is in universal employment; its strength in this country is twenty per cent. The *oleoresin* or ethereal *extract* (*Oleoresina Zingiberis*, U. S. P.) is a very concentrated form suitable to add to pills and boluses. Dose, a decigram or so. The official syrup contains three per cent. of the fluid extract, and the troches each about three minims of the tincture, with a little of the syrup. Ginger also enters into the compound rhubarb powder and the aromatic powder, both official.

A little of the preserved ginger of the shops makes a delicious and wholesome addition to the meal.

The alcoholic preparation popularly sold under the name of "Jamaica Ginger" is used to some extent, especially in mining communities, as an intoxicant. The cerebral effects have not been suitably studied, but are markedly distinct from those of ordinary alcoholism, there being narcotic effects apparently due to the ginger itself. A number of cases of blindness may be due to the employment of methyl alcohol. *Henry H. Rusby.*

GINGER, OIL OF.—This is an article of commerce, possessing the odor and flavor, but not the pungency nor full physiological effects, of ginger. It is pale yellow, with a specific gravity of 0.880 to 0.885, and contains camphene as one of its active parts.

Henry H. Rusby.

GINSENG.—A name applied to the roots of several species of *Panax* L. highly prized in superstitious Chinese medicine, and chiefly so used, though they have some mild aromatic properties (see *Araliaceæ*). The original Ginseng ("Schin-Seng") is *P. Ginseng* C. A. Meyer, of China, never seen in commerce here. The American variety, from *P. quinquefolium* L. (*Aralia q.* Decne), is chiefly exported to China and is bought eagerly, at high prices, by Chinese merchants for that purpose. It used to be very abundant in rich forest lands of the Eastern United States, but has been largely exterminated, except in remote sections. It is of very slow growth and, when well developed, presents two principal branches, and occasionally a small intermediate one. From this peculiar form, it is regarded as effective in determining the sex of the unborn child, whence its high repute in China. It contains considerable gum and starch and a little volatile oil and resin and the peculiar, but apparently inert, sweetish substance *Panaquilon*, soluble in alcohol and water. Obviously, there is no dose for so inactive a drug. *Henry H. Rusby.*

GLANDERS.—An infectious disease caused by the Bacillus mallei and characterized by foci of inflammation, often assuming nodular form, in the skin, subcutaneous tissue, muscles, and lungs. The disease is most commonly found in the horse; the cases in man arise by infection from the horse or some member of the Equidæ. According to Hecker,[1] the disease was first described under the name malleus in the fourth century. The first reliable observation of the disease in man was made by Schilling in 1821, and this was followed in 1837 by a monograph by Rayer[2] on the human form of the disease. The idea that the disease was contagious was held by all the early writers, and it was not until 1749 that Lafosse[3] affirmed it to be a spontaneous disease not transmitted by contagion. In 1840 the contagiousness of the disease was definitely established by animal inoculation.

The Bacillus mallei was discovered by Löffler and Schütz[4] in 1882. They isolated the bacillus in pure cultures, and by animal inoculations proved that it was the cause of the disease. The bacillus is slightly curved, not quite so long as the Bacillus tuberculosis, but somewhat thicker than this. The ends are rounded. It is non-motile in fluid cultures. It is a facultative anaërobe. In old cultures various involution forms are seen. The bacilli may grow out to long rods with irregular swellings along them, or they may form chains of small granules resembling cocci. In cover-glass preparations made from the lesions the bacilli usually appear somewhat longer and thicker than the tubercle bacilli, and show numerous sharply defined, clear, or faintly stained areas in their protoplasm. According to Csoker,[5] there are five pale and five dark points in each bacillus. They grow readily on most of the culture media, and have a characteristic growth on potato. On potato, after thirty-six hours in the incubator, a rather thick, colorless viscid growth appears which soon assumes a brownish tint and resembles honey in appearance. Later, the brown color changes to a dark reddish-brown, and the growth becomes thicker and more opaque, while the potato takes on a dark gray color. No other organism produces on potato exactly the same growth. The bacillus of glanders is one of the most easily destroyed of all the micro-organisms, and to this is probably due the relative infrequency of the disease. In pure cultures the bacilli die usually at the end of a few weeks, and they lose their virulence by the eighth day. Being vegetative forms only, heating to 55° or 60° C. for a few minutes destroys them. They are destroyed in the pus in forty-eight hours, when this is dried in a thin layer, and under the best conditions they will not stand drying more than three weeks. They are also very susceptible to the action of germicides. The bacilli are decolorized by the Gram stain. They easily stain in the basic aniline colors, but are easily decolorized. In sections they may be stained by Löffler's solution, but are less intensely stained than the nuclei of the cells. From the impossibility of staining them intensely it is often difficult to demonstrate them in tissues even when they may be present in considerable numbers.

A substance to which the name mallein is given is obtained from cultures of the bacilli. When this is injected into an animal affected with glanders in any form a characteristic reaction is produced which is diagnostic. This substance was prepared in 1888 by Helmen, a Russian veterinarian. Its diagnostic value was first demonstrated in 1891 by Kalming, of Dorpat, who became infected with the bacilli in the course of his laboratory experiments, and died of glanders.[5] Since this time its use as a diagnostic agent has become general. The mallein is obtained by the sterilization and filtration of a virulent culture of the bacilli in glycerin bouillon. The culture should be one month old. The filtrate is then evaporated to one-tenth of the weight of its volume, which gives a brownish syrupy fluid, and this is diluted ten times with one-half-per-cent. solution of carbolic acid. The dose is 0.5 cm. of the undiluted, or 5 cm. of the diluted solution. When this dose is injected subcutaneously into a healthy horse no reaction is produced. In a horse with glanders the injection is followed by extensive œdema of the subcutaneous tissue around the point of injection, chills, and an elevation of temperature which begins some hours after inoculation, reaches 3-4° C. above normal in twenty-four hours, and persists for several days. The method is especially important in making possible the diagnosis of latent glanders in which no lesions are evident. It is absolutely sure as a means of diagnosis when certain precautions which have been formulated by Nocard[7] are observed. The reaction can be considered typical only (1) when there is fever of from 1 to 5 degrees Centigrade; (2) when there is a large, hot, sensitive œdematous swelling around the point of injection; (3) when there is a general affection shown by weakness, loss of appetite, and muscular trembling. If there is no reaction, it is proof that the animal is not affected. It is necessary to see that the animal has no fever at the time and that afterward it is not exposed to weather conditions which may affect the temperature. In some of the animals which show the reaction there may be very insignificant lesions consisting only of a few small nodules in the lungs.

McFadyean[8] considers the local reaction of the most importance and sufficient alone for the diagnosis. In healthy horses there may be a slight local reaction, but the swelling is rarely more than three inches across and reaches its acme in from fourteen to sixteen hours. In infected horses the swelling is rarely under five inches across, often twice this, and continues to increase for twenty-four hours.

The ass is the most susceptible to natural infection, and the disease assumes a more acute form in this animal than in the horse. The mule is also more susceptible than the horse. Field mice are very susceptible, while white mice and rats are immune. Cats, guinea-pigs, squirrels, and rabbits are all susceptible in the order named; sheep and goats are less susceptible; dogs, birds, with the exception of the dove, beef cattle, and hogs are immune. Natural infection is very rare except in the Equidæ and in man. Lions and other carnivorous animals in menageries have been infected by feeding on the flesh of glandered horses.

In the horse various forms of the disease may be recognized, dependent upon its situation and acuteness of course. In the acute form the period of incubation is short. The disease begins with intense fever preceding all local manifestations. The prostration is extreme, the animal is insensible to excitation, locomotion is painful, the hair is rough, and there are muscular twitchings of the shoulders and chest. Appetite disappears completely, cold water is drunk greedily, and emaciation is rapid and extreme. According to Nocard,[9] the loss in weight may be more than 20 kgm. in twenty-four hours. These primary symptoms give place in from one to three days to the specific local symptoms. The lesions are in the mucous membranes and skin. The mucous membrane of the nose is intensely reddened or often of a violet tinge, and small ecchymoses may be seen. An abundant secretion flows from the nostrils; at first it is thin and watery, but later it becomes muco-purulent and often contains streaks of blood. In the swollen mucous membrane small pustules appear which open and give rise to small shallow ulcers, with raised edges and a bright red base. These ulcers rapidly enlarge, they become confluent and give rise to large irregular ulcerated surfaces covered with muco-pus. The ulcers are sometimes formed by the rupture of œdematous areas beneath the surface. In these areas extensive destruction of tissue seems to take place without any reaction, the softening finally extending to the surface. When the ulceration is advanced the nasal discharge is very abundant and contains fibrinous coagula and portions of necrotic tissue. While these lesions are taking place in the mucous membranes, hot painful tumors appear in various places, especially on the extremities, the flanks, and the shoulders. The œdema about them disappears, leaving hard, solid nodules which ulcerate rapidly. The ulcers become confluent, forming large irregular surfaces which produce an abundant, thin, odorless, often bloody pus. A similar infiltration extends along the course of the neighboring lymphatics, leaving hard cord-like swellings which ulcerate at various points and form thinner chains of ulcers uniting the larger. The lymph nodules belonging to the affected regions become swollen and indurated, finally breaking down into abscesses. The disease owes its name to the frequency with which the affection involves the lymph nodes (lymph glands). During this period the temperature continues high, often reaching 42° C. The loss of appetite and emaciation continue, there appear evidences of occlusion of the nasal respiratory passages, and at the last either general œdema of the lungs makes its appearance or foci of pneumonia develop. The acute form of glanders is always fatal, the disease lasting from eight to thirty days.

The chronic variety of the disease does not take the definite course of the acute, and may assume a number of forms which differ so much the one from the other that they have been regarded as different diseases. Thus the skin lesions have been considered a separate disease under the name of farcy. In the two classic types of the chronic form the predominant lesions are found in the one in the skin, and in the other in the mucous membranes and parenchymatous organs. The chronic lesions are of the same general type as the acute, their evolution is much slower, and their special characteristics are better marked. The first lesions to appear in the skin are the hard nodules (farcy buttons) followed by ulceration. Hot, painful, œdematous tumors appear in various places in the subcutaneous tissue, especially where the skin is thin and the subcutaneous tissue abundant. These tumors may be the size of a nut or of an egg. Gradually they become smaller in size by the absorption of fluid, and the central mass becomes hard and definitely circumscribed. The hair falls out, the skin becomes thinned, and finally an abscess is formed which contains a viscid yellowish liquid streaked with blood. The opening does not close, and the abscess gives rise to an ulcer. The edges of this are elevated and covered with thick granulations. The ulcer may extend laterally or in depth, both by continuous extension and by the formation of neighboring nodules which follow the same course and finally unite with the main ulcer. The skin in the vicinity is hard and indurated. The ulcers may finally cicatrize. The same swelling which preceded the formation of the nodules and ulcers extends along the subcutaneous lymphatics. The acute swelling subsides, leaving a hard cord (farcy pipe). A number of lymphatics may be affected, giving rise to a network of cords. These may persist for a long time without change, or in some cases nodular swellings appear along them at intervals, and these nodules may soften and ulcerate in the same way as the nodules first described. The ulceration may extend between adjoining foci along the course of the vessel and in this way large irregular ulcerated tracts may result. The lymph nodes are swollen and become finally converted into hard, indurated, adherent masses. They rarely soften and give rise to abscesses as in the acute cases.

The specific affections of the nose are very similar to those in the skin, with differences due to the different character of the tissue. They consist in the formation of nodules and in ulceration which may terminate in extensive cicatrization. The nodule is preceded by a diffuse swelling of the tissue. The nodules are round, hard, and much smaller than those of the skin. The centre softens and is discharged, leaving a shallow irregular ulcer with elevated edges. Large irregular ulcers are formed by the union of adjoining ulcers. The edges are hard and indurated, and cicatrization is often found in one part while the ulcer is extending in another. Dense white radiating cicatrices are found, and these are the most characteristic lesions of the disease (Fig. 2298). The ulcers may extend in depth, both cartilage and bone may be destroyed, and perforation of the septum may be produced. The nasal discharge varies in character and amount, depending on the character of the lesions. It is more abundant while the animal is at work. In the beginning of the process it is thin and watery, but later it becomes muco-purulent. In some cases a lymphatic fluid is discharged which coagulates on exposure. When the ulceration is marked it may contain necrotic tissue, and when large vessels are opened by the extension of the ulcers there may be epistaxis. The lesions in the lungs which may be very extensive, do not give rise to any characteristic symptoms. There may be cough and evidence of respiratory trouble, and when the pleura is involved in the process there may be the physical signs denoting this.

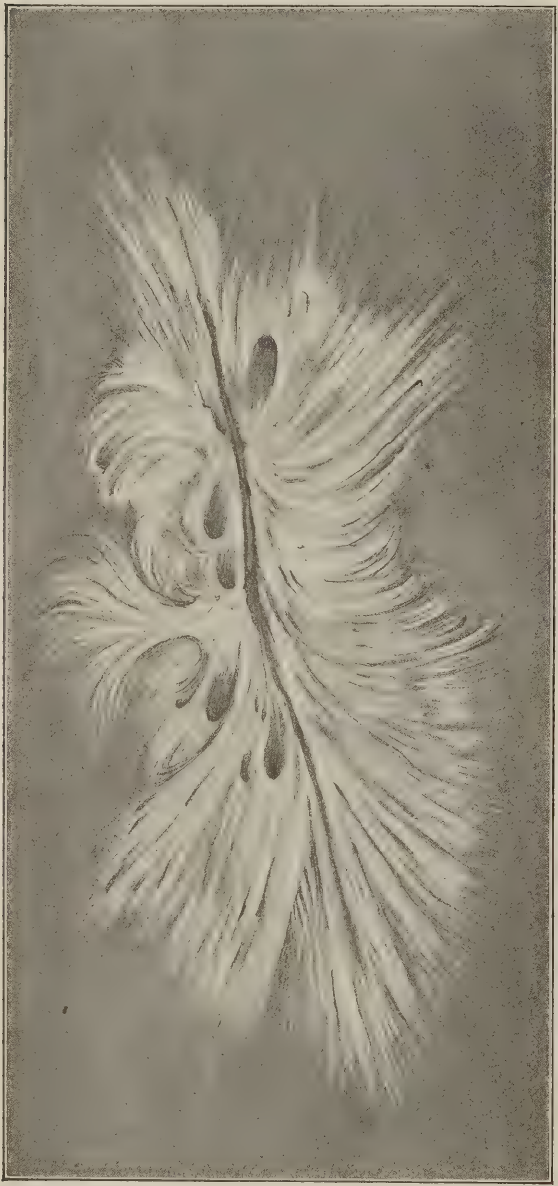

FIG. 2298.—Stellate Cicatrix from Nasal Septum. From a case of chronic glanders. (Kitt.)

In addition to these more common conditions of chronic glanders there are others which are only occasionally met with. A diffuse swelling of the subcutaneous tissue, at first hot and painful, later indurated and contracted, much resembling the nodule in its general features, may take place. The induration becomes brawny and may ulcerate at several points. In stallions swelling of the testicle is often seen and may form the first symptom of the disease. The gland is at first greatly enlarged, hot, and painful. The acute swelling and œdema subside after some days, and then the gland is felt to be indurated and the cord thickened. Affections of the joints varying in degree are not uncommon. The disease may last for an indefinite time. Often all the symptoms disappear for a long time and then again break out. A considerable proportion of the cases end in recovery. Semmer[10] has described a rather benign form of glanders which he thinks is more common in South Russia than elsewhere. The animals react to mallein in the same way as in the malignant disease, but very slight lesions are found at the autopsy.

When the disease is produced experimentally in the horse or ass by introducing the bacilli into scarified surfaces or by injecting them subcutaneously, the acute form is produced. Strauss[11] in 1886 showed that the intraperitoneal injection of the bacilli in the male guinea-pig was followed by characteristic lesions, and this method is one of the best and surest for confirming the diagnosis of the disease. Inoculation into the peritoneal cavity is followed, on the second or third day, by a recognizable degree of swelling of the testicles. The swollen testicles are painful, and the skin of the scrotum is red or violet and adherent to the underlying glands. The lesions reach the greatest intensity by the sixth or eighth day, and the animal dies in twelve or fifteen days. The method is not absolutely sure as a diagnostic test, and for several reasons. Nocard[12] has shown that an affection of horses, characterized by swelling and ulceration of the extremities, is due to a bacillus which will produce lesions in the testicle similar to those observed in glanders. In other cases the guinea-pig may die of septicæmia due to entry of the bacilli into the blood before the characteristic lesions of the testicle have had time to develop. For this reason some prefer to inoculate subcutaneously.[6] The inoculation had better be made with a pure culture than with the products of disease containing the bacilli, for the glanders lesions may be masked by an infection with pus organisms. In an early stage the lesions of the testicle consist in small, yellowish foci in the tunica vaginalis, or the two surfaces may be united by a thick purulent exudation containing numbers of bacilli.

In man the disease appears in both the acute and the chronic form. Taken in its entirety the clinical history of the disease, both in the acute and in the chronic form, is almost characteristic, but at a given period, and indeed for a long time, it may be impossible to make the diagnosis. This is particularly true of the chronic form. In general, the disease in man presents many points of similarity to the equine disease, but there are notable differences. The skin lesions which are so prominent in the horse appear in man only in the later stages of the disease, and abscesses in the muscles (which are very rare in the horse) are common in man and often constitute the first evidence of the disease. The disease is comparatively rare in man despite his evident susceptibility to the action of the organism and his frequent opportunities for infection. In the last ten years in Boston I have seen but two cases of infection in man despite the fact that the disease is not rare in horses. The fact that the disease is not an extremely common one in both animals and man must be attributed solely to the slight viability of the organism and to the fact that it cannot lead a saprophytic existence.

The acute disease begins in man with chills and high fever, which sometimes takes a typhoid form. There is often intense pain in the joints and muscles, with general weakness and malaise. This condition is followed by the development, in the muscles or subcutaneous tissue, of hard swellings which rupture and discharge a thick mucoid pus mixed with streaks of blood. Even at an early period of the disease the skin over almost the entire body may be covered with pustules. In some cases there is a diffuse erysipelatous inflammation of the skin preceding the formation of pustules, or large ulcers may be formed by necrosis of the skin. The ulcers show no tendency to heal and become covered with thick, pale granulations. The nasal discharge is not so marked as in the horse, but an examination of the mucous membrane will rarely fail to show nodules, ulcers, and diffuse swelling. In two of Küttner's[13] cases the frontal and sphenoidal sinuses were affected, the most evident lesion being the great swelling of the mucous membrane. The muscle abscesses are usually present. Although all the muscles may be affected, the lesions are most common in the biceps, the flexors of the forearm, the rectus, and the pectoral muscles. The pustules of the skin are most common toward the termination of the disease and often appear only just before death. The pustules may be seated immediately beneath the epidermis in the corium or in the subcutaneous tissue. They may somewhat resemble smallpox pustules, but they vary greatly in size and are not umbilicated. Tedeschi[14] has reported a case in which there was a terminal acute meningitis. In some cases it is possible to find the atrium of infection. The disease may begin by abscess and ulceration at this point and the generalization take place by an acute lymphangitis. In many cases, and those the most severe ones, it is not possible to determine how the infection took place. This acute form of the disease is almost invariably fatal, death taking place usually between the sixth and the thirtieth day of the disease.

The chronic form may have a duration of several years. Hallipeau[15] has reported a case of six years' duration. The well-known case of Aufrecht, reported by Kernig,[16] lasted for one year and a half. In these cases there is usually an infection from a local lesion of the extremities followed by a lymphangitis extending to the lymph nodes. The local lesion may take the form of an ulcer; and abscesses may develop, followed by ulceration, the infection extending along the lymphatics. The hard cord-like affection of the lymphatics which is seen in the horse, does not take place in man. Later, abscesses appear in the subcutaneous tissue or in the muscles in various places. In some cases these muscular abscesses form the only evidence of the disease. In the case reported by Hallipeau there were numerous abscesses at intervals during the first three years of the disease, but they did not exert much influence on the general condition. These healed spontaneously in some cases, and in others after cauterization. There was then a period of latency for three years, followed by an acute attack and death. In the case reported (Kernig) the first anatomical evidence of the disease was a hard nodular swelling in the calf of the leg. This was followed after a long interval by an infiltration of the abdominal wall resulting in suppuration. Sommerbrodt[17] gives a case in which the symptoms were chills with fever and intense pain in the extremities. Two weeks after entry into hospital death took place from acute glanders. In the case reported by Neisser[18] the disease began as a small ulcer at the internal angle of the eye, and this was followed in two months by the development of an abscess in the left cheek; then later a purulent discharge from the ear and nose set in, abscesses developed in different parts of the body, and ulcers formed on the hard palate, in the nasal cavity, and in the larynx. In nearly all of the chronic cases reported the disease passes into an acute form a short time before death. The most common lesion in fatal cases of both the acute and the chronic form, consists of pustules of the skin, particularly on the face. Chronic glanders has a very much smaller mortality than the acute, Sims Woodhead[19] placing it at forty per cent.

The characters of the lesions are similar in both animals and man. The glanders bacillus seems to exert about the same influence on all tissues, and the lesions vary only in the intensity of the action set up and in the different degree of reaction of the surrounding tissues. There has been a general misconception among German authors as to the character of the lesions. Virchow, who studied the macroscopic character of the lesions more than the histological details, lays particular stress upon the nodular character of the lesions, and places the disease among the granulation tumors. Baumgarten compares the nodule with the tubercle, and says that it differs from this, as regards its histogenesis, chiefly in the participation of the polynuclear leucocyte in its formation. In the glanders nodule the polynuclear leucocytes play the part that the lymphoid cells do in the tubercle, the main mass of the nodule in both being formed of epithelioid cells derived from the fixed cells of the tissue. The anatomical descriptions of the lesions given by French authors are more correct. An excellent account of the histology and the histogenesis of the lesions in man and in the guinea-pig is given by Wright.[20] I have been able to study the lesions in the horse by aid of a number of specimens furnished by Dr. Frothingham and by the examination of preparations secured by Drs. Wright and Magrath from human cases autopsied by them.

The most characteristic lesions in the lungs are the nodules or tubercles. These are found more frequently, and their characteristics are better marked, in the horse than in man. They may be found in any part of the lung, but are more numerous beneath the pleura than elsewhere. In their most characteristic form they vary in size from a pin's head to a pea, and are hard and circumscribed. On section they show a dry, opaque, central mass, which can often be pressed out, surrounded by a pale transparent zone (Fig. 2299). On microscopic examination the centre is found to be composed of granular *débris* in which no tissue can be recognized. On the outside of this is a zone composed of epithelioid and giant cells with considerable lymphoid infiltration and firm

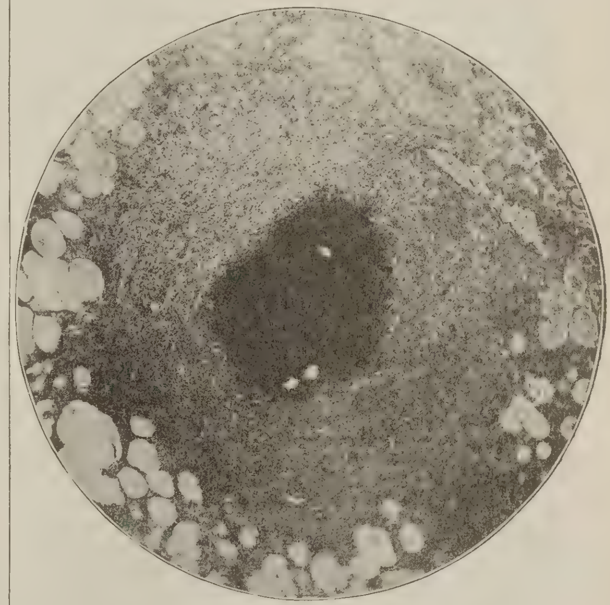

FIG. 2299.—Section of Chronic Glanders Nodule in the Lung of Horse. The dark central mass is composed of cell and nuclear débris in which no lung structure can be recognized.

intercellular connective tissue. Immediately around the central mass of *débris* is often a mass of large phagocytic cells similar to the cells in the corpus luteum. On the outside the connective tissue extends into the surrounding lung structure as a thickening of the alveolar walls. In some of these nodules the central necrotic mass may be extremely small or it may be absorbed completely by the surrounding granulation tissue, the entire nodule being transformed into a small mass of connective tissue. Lime salts may also be deposited in the necrotic centre. The histogenesis of this more fully developed nodule, which very much resembles a tubercle, can be studied in those less advanced. Such a nodule is seen in Fig. 2300. In this the structure of the lung is preserved in the centre, and around this is a definite zone of connective tissue. In the dark central area the tissue is entirely necrotic, and the cells both in the exudation and in the walls are broken down and represented by nuclear detritus. In the tissue around this the necrosis is not so complete, and there is some thickening of the alveolar walls due to the formation of connective tissue. This passes in turn into the surrounding connective-tissue capsule. A more diffuse and earlier nodule is shown in Fig. 2301. In this there is a centre which is situated in close proximity to an interalveolar septum in the lung, and which is composed of a dense cellular exudation in the alveoli. All the cells in the exudation are broken down, the dark color of the centre here as in the other figures being due to the immense amount of nuclear detritus. In the surrounding alveoli there is an exudation composed of fibrin, of fragmented leucocytes, of coagulated serum, and of effused blood. In all of the younger nodules hemorrhages play an important part, and we may find areas represented by hemorrhages alone. Fig. 2302 shows a much larger area in which there are several centres filled with the closely packed nuclear detritus and around these there is an exudation similar to that in Fig. 2301. Nocard lays great stress on the presence, in the early cases, of small, rather transparent nodules in the lung close beneath the pleura. They may appear as early as on the third day after infection. They are formed by a small area of exudation surrounded by intense hyperæmia and hemorrhage. One thing is striking in the examination of all these nodules: they are not in relation to the bronchi. In all of the figures bronchi but little altered can be seen in the vicinity of the nodules. In the material at my disposal it has not been possible to trace the formation of these masses by serial sections, but they do not appear to be due to a bronchiogenic infection of the lung by the bacilli. They occur in the lung with too great regularity and at too early a stage to suppose them due to an infection coming from the air passages higher up. In addition to such nodules it is not uncommon to find areas of diffuse pneumonia. In the horse these are often definitely lobular. In man they resemble more closely the areas of embolic pneumonia. They may be composed of cellular and hemorrhagic exudation in which there are large areas filled with nuclear detritus. The bronchi in these foci are filled with the same exudation as that in the alveoli. In some cases the surrounding interlobular tissue is greatly thickened from an infiltration with masses of lymphoid cells, and the adjoining lung tissue is involved to a greater or less extent. Such an area is represented in Fig. 2304, which shows a longitudinal section of a large bronchus filled with exudation. In the horse foci the size of an apple and manifesting evidences of purulent exudation may be found, and these may break down so as to form abscess cavities. In man the lung lesions are rarely absent, but at the same time they rarely take the distinctly nodular form which is so often seen in the horse. In the chronic cases fibrous nodules have been described, but no detailed description of their tissue has been furnished. In the acute cases the lesions, always present, take the form of larger and smaller foci of pneumonia and abscess-formation. Hyperæmia and evidences of hemorrhage are always found in the vicinity, and there are occasionally large areas of effused blood similar to infarctions. The pneumonia areas may resemble the nodules in having a centre totally necrotic and filled with nuclear *débris* and around this a less intense fibrinous, cellular, and hemorrhagic exudation. The liquefaction of the exudation gives rise to abscesses. In man also

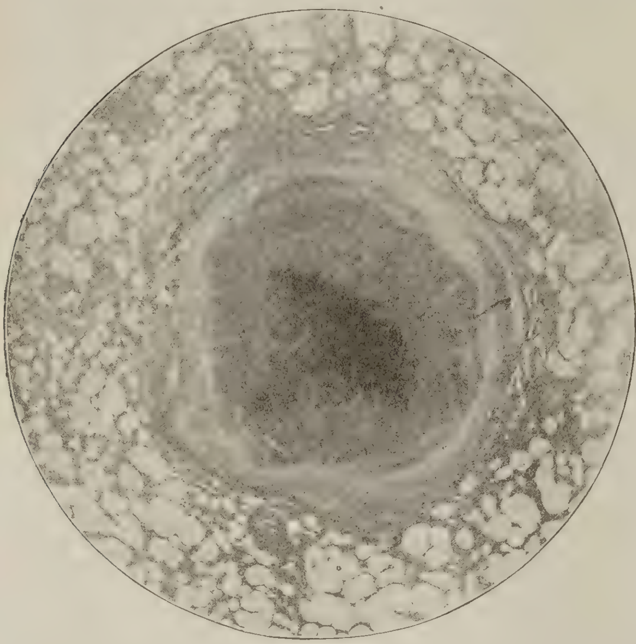

FIG. 2300.—Section of Chronic Glanders Nodule in the Lung of Horse, less advanced in its formation than Fig. 2299. In the centre of the nodule the lung structure is still visible.

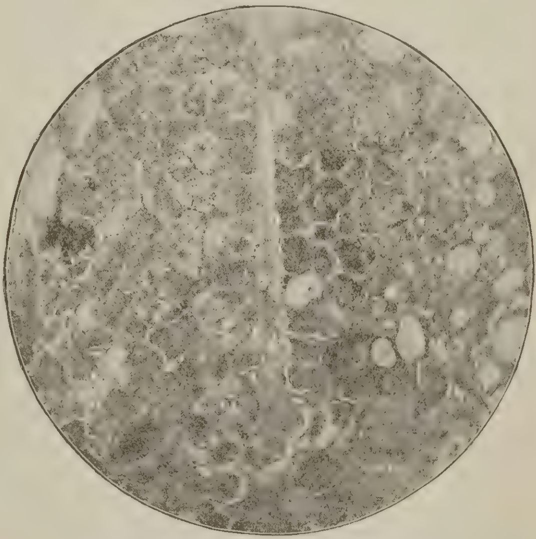

FIG. 2301.—Section of Beginning Nodule in Horse's Lung Adjoining an Interlobular Septum. The darker central portion is composed of cellular and nuclear detritus. The walls of the alveoli are necrotic.

the foci are more frequently found beneath the pleura. There is no reaction in these acute cases on the part of the lung. It is not an uncommon thing to find abscesses without any walls, representing cavities in the tissue surrounded by hemorrhagic and partly necrotic lung tissue.

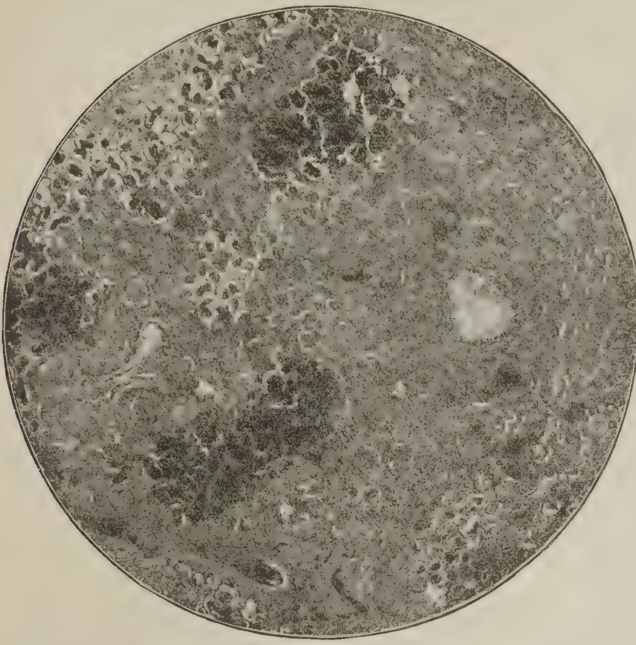

FIG. 2302.—Section of More Diffuse Acute Nodule in Lung of Horse Showing Several Centres.

There is rarely opportunity to examine the more chronic abscesses in the muscle. In those of an acute character the contents are composed of cell and nuclear detritus with scarcely a single cell showing well-preserved nucleus and protoplasm. In a small abscess in the pectoral muscle, in one of our cases, the abscess cavity contained on the edge a small amount of detritus, and all around there were degenerated and hyaline muscular fibres. There was no reaction on the part of the tissue and little or no surrounding cellular exudation. The muscular fibres seemed literally to melt away in the process.

The skin nodules (farcy buttons) in the horse are formed by an intense leucocytic infiltration of the skin and subcutaneous tissue with numerous foci of hemorrhage. In the beginning intense congestion and œdema of the surrounding tissue are present. There is also a proliferation of the fixed cells with formation of epithelioid and giant cells. The epidermis over the nodule may be infiltrated with cells and penetrated by the exudation. The hairs become loosened and drop out. The central area where the exudation is most intense becomes necrotic, the epidermis over it shares in the necrosis, and an abscess forms. The latter is likely in time to become converted into an ulcer. In other cases the necrotic mass may remain in the tissue and be gradually absorbed by a surrounding mass of granulation tissue. The formation of the skin nodule is very similar to the formation of the lung tubercle. The affection of the lymphatics giving rise to the so-called glanders cords (farcy pipes) pursues the same course as that in the nodules. There is an exudation in and around the lymphatics in the subcutaneous tissue or in the cutis. This is accompanied by intense congestion and œdema of the surrounding tissue. The whole central mass undergoes necrosis and may remain for a long time as a hard cord gradually undergoing absorption, or it may soften from place to place, or along its course, and give rise to ulcers. In some cases the necrotic tissue is discharged as a single mass. In man the skin lesions are somewhat similar to those produced by the streptococcus. In some places there seems to be very little reaction on the part of the surrounding tissues, and abscesses similar to those in the muscles are produced. Such abscesses are in the subcutaneous tissues. Sections made from the large areas of infiltration show lesions affecting both the skin and the subcutaneous tissue, but they are more marked in the skin. This shows an intense general infiltration with leucocytes and foci composed of these. The glands of the skin and hair follicles are often embedded in this and show but little change. Most of the exudation cells are broken down, and in places there is nothing but a mass of nuclear detritus. The epidermis over the area shows various changes, some of them almost peculiar to the disease. In some places the entire epidermis is cleanly separated from the tissue beneath by an exudation. In other cases and over small areas only the horny layer of epidermis remains, elevated, and covering a mass of cellular and nuclear detritus formed by leucocytes and the fragments of epithelial cells and nuclei (Fig. 2305). In still other cases there is a peculiar condition caused by a fluid exudation which has extended into the epidermis and has separated the cells. In the epidermis there may be found foci which are composed of masses of epithelial cells each separated from its connections. In the loose subcutaneous tissue there may be a considerable amount of fibrin in the exudation. The cellular infiltration may extend down deeply into the muscle, the fibres of which undergo necrosis. There are but few lymphoid cells and epithelioid cells in the surrounding tissue. In places the connective-tissue nuclei and the endothelial cells of blood-vessels and lymphatics have large vesicular nuclei with but little chromatin. The nuclei become increased in number, and no nu-

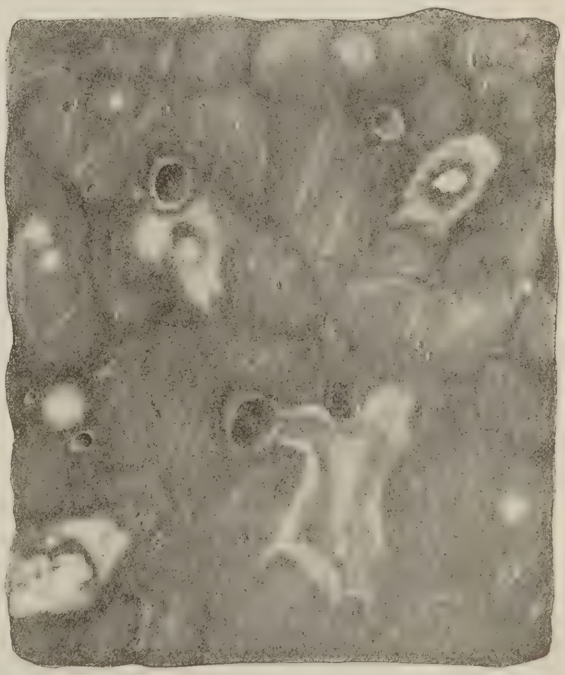

FIG. 2303.—Section of Lung of Horse (Natural Size), Showing Nodules and Cicatrices. The lobules are more prominent than is natural. (Kitt.)

clear figures are found, but occasionally there are biscuit-shaped nuclei. The process is one of degenerative direct nuclear division, and not a true proliferation of cells. The smaller vesicles and pustules show the same condition, but in these the process is confined to the dermis. The blood-vessels in the lesions and in their vicinity are often found thrombosed. The thrombi may be composed of cells, the nuclei of which show the fragmentation which is so common a feature. Nothing can be seen of the lymphatics where the process is most intense, but a study of the surrounding œdematous tissue shows that the same condition can be found here which is so common in the horse. Both the smaller and the larger lymphatics lying in a tissue which shows no lesion beyond a slight cellular exudation and the separation of the fibres due to the œdema, may be filled with masses of cells and nuclear detritus (Fig. 2307). In some cases the process extends through the wall, and a small abscess may be formed of which the lymphatic is the centre. Fig. 2306 shows such an area. The space in the centre represents the vessel from which the exudation has fallen in the preparation of the specimen.

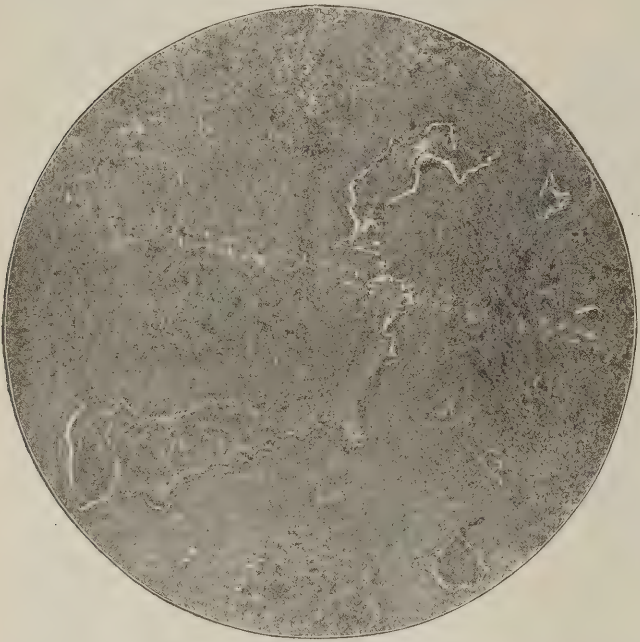

FIG. 2304.—Section of Chronic Lobular Glanders Pneumonia from Lung of Horse Showing a Large Bronchus in the Centre Filled with Exudation. In addition to exudation and hemorrhage in the alveoli there is marked connective-tissue formation.

The lesions in the mucous membranes are similar to those in the skin, with the exception that there is a great deal more extensive proliferation of the fixed cells. I have not had an opportunity to examine any of the distinct nodules formed in the mucous membrane, nor have I examined any of the chronic lesions. In the acute cases, in which swelling of the mucous membrane is the most marked characteristic, there is a dense accumulation of lymphoid and epithelioid cells in this membrane. Polynuclear leucocytes are numerous, both diffusely scattered among the other cells and in small masses chiefly on the surface. However, the individual accumulations of these leucocytes are never so large here as they are in the other tissues. Many of them, especially those scattered diffusely, have normal nuclei, but in most of them the nuclei are fragmented. The epithelium is for the most part destroyed, only fragments of it remaining. The participation of the connective-tissue cells in the process is shown in the horse by the enormous radiating cicatrices formed in the healing (Fig. 2298). It is difficult to explain these differences in the character of the process in the mucous membrane except by the assumption that in the mucous membrane there is a comparatively free opportunity for the escape of the exudation, carrying with it both the bacilli and the toxic products.

The lesions in the testicles consist in the presence of small foci of suppuration in the tunica, rarely in the testicle itself. In the other viscera the lesions are unimportant. One case of death from acute meningitis in man is reported by Tedeschi, the infection of the meninges having taken place, most probably, by way of the blood. Abscesses have been described in the liver in several cases in man, but they are more common in animals, particularly in the guinea-pig. Several cases also of abscesses of the bone marrow have been reported, and in the Tedeschi case of meningitis there was osteomyelitis of the tibia following an abscess. I have not found any descriptions of cases of acute nephritis, and in the kidneys of the human cases examined by me the degenerative lesions were slight. Nor are there any of the focal necroses in the liver which are so frequently found in other infections. There is some swelling of the spleen in the acute cases, but the lesions are confined to hyperæmia. In the lymph nodes there may be abscesses and foci of leucocytic infiltration.

The relation of the bacilli to the lesions is obvious. The bacilli are always present, but in variable numbers. In some cases they may be numerous, and in others they are found only after long search. They are difficult to find in sections, for there is no distinctive stain for them, and they are colored less deeply than the fragments of nuclei. They are found in the exudation and not in the surrounding tissue. They are always associated with the products of the disease, and the free discharge of these products from the affected mucous surfaces gives every possibility of the extension of the infection. When the bacilli enter the tissues they may or may not produce a lesion at the point of entrance. In Wright's case there was an intense inflammation of the thumb where the infec-

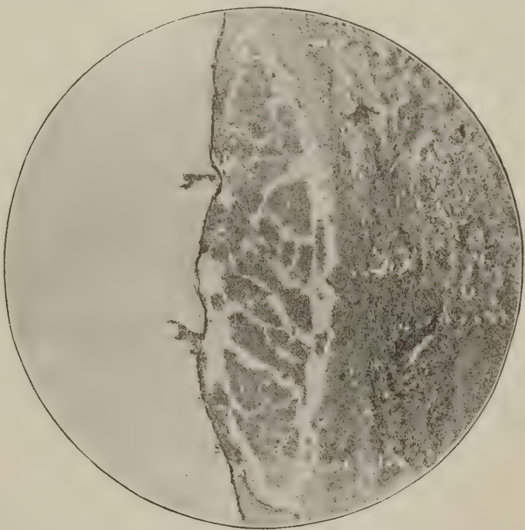

FIG. 2305.—Section of an Unruptured Pustule in the Skin of Face from an Acute Case of Glanders in Man. The horny layer is still intact. The other cells of the epidermis are necrotic and their fragments are mingled with the exudation.

tion took place, and this was followed by gangrene. In one of Küttner's cases in which the infection took place in the foot, there was a large ulcer on the heel. In other cases there has been no local lesion at the probable point of infection, or else it was of an insignificant character. The bacilli rapidly enter into the lymphatic circulation and into the blood. From the blood they may be deposited in various tissues, and in many cases they remain in the blood or are again introduced into it, and so give rise to septicæmia. They have repeatedly been found in the blood in acute cases in both animals and man. They may be found in cultures, on microscopic examination, and by inoculating other animals with the blood. The situation of the lesions points to blood infection, but the bacilli, probably generally distributed, find in but few tissues suitable conditions for growth. There are great differences in this respect in different animals. Thus the testicles which are constantly affected in the guinea-pig are rarely affected in the horse, and still more rarely in man. Abscesses in the muscles, frequent in man, do not occur in the horse. There seems to be an equal tendency in all animals to affections of the lungs, skin, and mucous membranes of the nose. There is little probability that the lesions in the nose come from surface infection. They are almost constantly present even in cases in which the infection surely was from other surfaces. Wherever the lesions are produced by the bacilli they tend to extend further by means of the lymphatics. This is seen particularly in the skin and also in the diffuse lesions in the lungs. The general character of the lesions is the same in all animals. The bacilli produce a rapid and abundant exudation of polynuclear leucocytes. These form the central focus. Around these foci there will be found evidences of intense congestion, of hemorrhage, and of fibrinous and serous exudation. These changes will be found to be less marked in the mucous membrane. The bacilli are found in greatest numbers or exclusively in the central mass of leucocytes. Destruction of the leucocytes and of the tissue containing them rapidly follows. The cells are fragmented and the nuclei converted into masses of nuclear detritus. The broken-up chromatin has a peculiar way of flowing together and forms large irregular clumps. In some cases a single well-preserved leucocyte is found in the central exudation. Lymphoid cells may be found in the surrounding tissue, but none in the centre. There is no other infectious process which produces such complete destruction and disintegration of the exudation cells. In certain cases in which the bacilli are less virulent or the tissues more resistant or in which unknown favoring conditions are present, there is a marked reaction of the surrounding tissues leading to the formation of an encircling band of granulation tissue and afterward of connective tissue. In the mucous membranes the tissue reaction is more marked than in either the lungs or the skin.

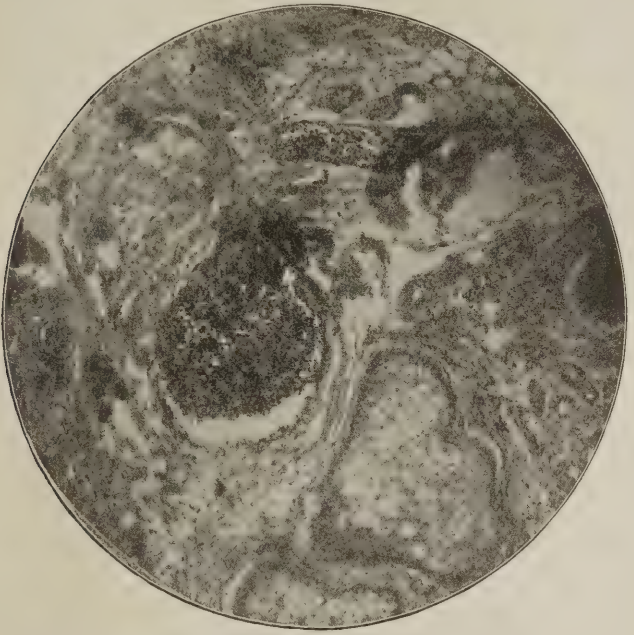

FIG. 2306.—Section of the Human Skin in the Vicinity of an Area of Infiltration and Pustule Formation Showing a Lymphatic Filled with Cellular and Nuclear Detritus. Slight cellular infiltration in the surrounding tissue.

Mixed infections occur, but they are not the rule. Streptococci have been most frequently found as the accompanying organism.

The way in which the bacteria infect the surroundings is apparent from the situation of the lesions. Everything that the horse touches, everything in his vicinity may become contaminated and a conveyer of the organism. The abundant discharge from the nose, which by the snorting of the animal may be thrown a considerable distance, contains the bacilli in large numbers. The abundant discharge from the skin ulcers contains them. They are contained in the urine even when there is no lesion in the kidney, and they pass through the vessels of the placenta. The skin becomes contaminated either from the ulcers or from the nasal discharge. The harness, especially the bridle or halter, the stall, the litter, the food, the drinking-vessels all become infected. There is little doubt that many cases of infection in horses take place from the public drinking fountain. The water becomes infected from a horse with

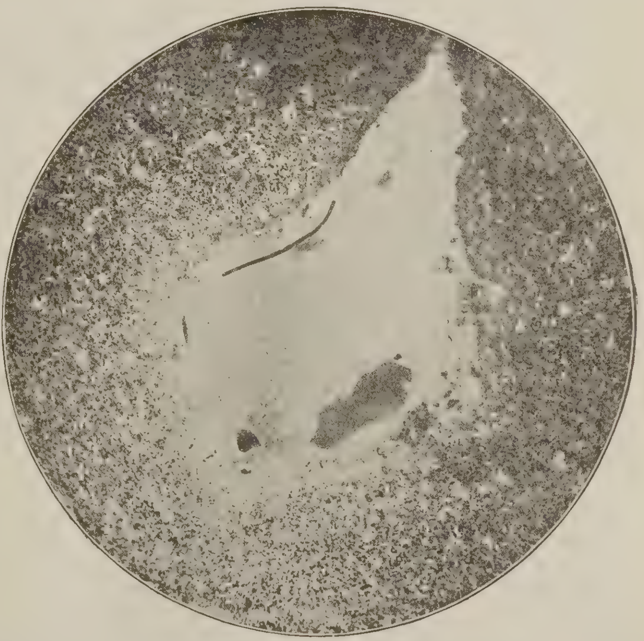

FIG. 2307.—Section through a Small Abscess in the Dermis which has Formed Around a Lymphatic. The space in the centre represents the lymphatic from which the contents have been lost.

nasal discharge, and a horse drinking shortly afterward from the same fountain will almost surely be infected. Close contact of the horses favors infection. Thus horses in a pasture where they are mouthing each other and where the food is infected are more apt to acquire the disease from one another than are horses in a well-managed stable. Not only the acute but the chronic cases are a source of infection. Chronic cases which show no evidence of the disease and which have only a few nodules in the lung are often the sources for infection. Nocard relates cases in which the disease persisted in stables, and the source was discovered only by the use of mallein. Infection in the horse takes place most usually from the intestinal canal. It may be conveyed either in the food or in the drink. Nocard gave twenty horses water to drink in which he had mixed a pure culture of the bacilli. All acquired the disease, reacted to mallein, and at autopsy showed in the lungs the small acute lesions on which he lays so much stress. Infection generally takes place from small lesions in the mouth, which are very generally present and which are due to the coarse fodder. It may also take place from lower down in the intestinal canal. Infection by the respiratory tract is rare. Babes caused guinea-pigs to breathe dust mixed with a dried culture, and succeeded in producing infection in two out of four cases. Nocard found that when virulent cultures were mixed with dust, dried, and injected into the peritoneal cavity of the guinea-pig there was no result. Cadeac injected a pure culture directly into the trachea of an ass without producing infection. Infection through the uninjured skin probably does not take place in natural conditions. Both Babes and Nocard succeeded in infecting guinea-pigs by rubbing the skin with pure cultures mixed with vaseline, but Nocard was not able to infect the ass in this way.

The disease in man is almost confined to those concerned in the care of horses, as coachmen, stablemen, etc. It is curious that more cases are not found in women, in view of the way in which they sometimes lavish caresses on a favorite horse. I have found but two cases in which infection has taken place from man to man: one the well-known case of Aufrecht (infection from autopsy), and a case reported by Zowadski[21] in which a physician infected himself in opening a supposed pyæmic abscess of the leg. Both physician and patient died of glanders. The mode of infection seems in a number of cases to be from small wounds of the skin which become contaminated with the virus. There have been several cases in which the infection took place from the conjunctiva which had become contaminated by the snorting of a glandered horse. In many cases the mode of infection is unknown, and even in a number of cases in which, from the situation of the first lesions noticed, the infection seems to have taken place from the skin, it is not certain that the skin lesions were not secondary.

Diagnosis.—A careful study of the phenomena of a case of acute glanders in man, from the beginning to the terminal pustular eruption of the skin, will generally enable us to make a diagnosis with some certainty. The diagnosis should always be made and can be made with certainty by the examination of the products of the disease. The microscopic examination of the pus from an abscess in the muscles of an extremity, showing the complete destruction of cells and nuclei, together with the presence of bacilli resembling glanders bacilli morphologically, is almost sufficient to make the diagnosis. Certainty can be reached by culture of the suspected material and by inoculation of a guinea-pig. In one of the acute cases seen here in Boston, the diagnosis was made from the microscopical and bacteriological examination of the sputum. Early in the disease when the symptoms may simulate typhoid fever, acute articular rheumatism, or some other acute infection, the diagnosis cannot be made. The disease so rarely appears except in those concerned with the care of horses that the occupation should be carefully considered. When the lesions are established and when it is possible to examine their products,—whether they are abscess contents, lung expectoration, or nasal discharge,—the diagnosis can and should be made by bacteriological examination and animal inoculation. In those cases in which there is an abundant pustular eruption the disease may present some similarity to variola. It can be distinguished from this by the character of the pustules (the almost universal absence of the umbilication; the varying size; the accompanying bullæ with frequently hemorrhagic contents; the subcutaneous abscesses, the loss of epidermis without actual suppuration; and the grouping of the pustules, in glanders). Very little is known of the use of mallein in man. Bonome[22] reports a chronic case (in a man and of three years' duration) in which mallein was given as a therapeutic agent and in which recovery took place. It produced a violent reaction. It has not been used sufficiently to determine its value as a diagnostic agent in the case of human beings.

In horses there is little difficulty in making the diagnosis when the disease is established, and in cases of doubt the careful administration of mallein will settle the diagnosis.

Treatment.—The treatment of glanders in man should be directed to the relief of the conditions. Abscesses and ulcers should be treated surgically. There is no reason to believe that the course of the disease can be influenced by the internal administration of drugs. Mercurial preparations have been used and they are recommended by Koranyi. All medication has been used with the greatest effect in chronic cases, and in estimating the results of treatment it must be remembered that a large percentage of these cases recover independently of treatment. There should be no attempt at treatment of animals, but they should be killed when the diagnosis is made, or, in case the necessary knowledge for making this is not available, when the disease is suspected.

With our present knowledge of the bacteriology and pathology of the disease, the sources and modes of infection, there should be no excuse for the existence of the disease. No disease could be more easily stamped out. The Equidæ are the sole source of infection. The disease is easily recognized by the mallein test, which should be made in all suspected cases. If there is a suspicious case in a stable, and this case gives a positive reaction, all the animals in the stable should be tested. It may happen that a chronic case with slight lesions located in the lungs, and giving rise to no suspicious symptoms, can be a constant source for spreading infection. Public drinking-fountains undoubtedly assist in the extension of the disease.

W. T. Councilman.

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GLAUCOMA.—The name of this affection of the eye has been bestowed upon it on account of a greenish appearance (γλαῦκος) of the pupil, which, although present only in rare cases, may be observed as one of its symptoms. This name is a misnomer. It is, however, generally adhered to. More recent names, which were adapted to special theories regarding the character of the affection—as, for instance, ophthalmia arthritica, choroiditis serosa, etc.—have never been universally adopted.

PATHOLOGY.—The chief characteristics of glaucoma are a slowly or rapidly progressing diminution of the acuity of vision, combined with an occasional or continued increase of the intra-ocular pressure, and an excavation of the optic-nerve papilla. Around these chief symptoms and conditions we find grouped a number of other symptoms which characterize the different varieties of the disease. These varieties are known as *glaucoma simplex acutum*, *glaucoma simplex chronicum*, *glaucoma inflammatorium acutum*, *glaucoma inflammatorium chronicum*. When any one of these forms of glaucoma occurs in an eye which has not previously been affected in a manner such as to cause the development of glaucoma, we speak of the glaucoma as being *primary;* when, on the other hand, a previously diseased eye is, in consequence of this former disease, attacked by glaucoma, we call it a *secondary* glaucoma. We can furthermore, as a rule, recognize three stages in the development of all forms of glaucoma, the first of which is called the *prodromal* stage, the second that of *glaucoma evolutum*, and the last that of *glaucoma absolutum*.

What are usually described as the *prodromes* of glaucoma are observed in a large majority of the cases, and are in reality a series of slight attacks of acute glaucoma. This prodromal stage may last for many months, or even for years, until the attacks and their consequences become more serious. The prodromal attacks are not equal either in duration or in degree; yet they are not serious enough, as a rule, to cause cupping of the optic disc, nor to reduce the visual acuity lastingly. On the other hand, their early recognition is of grave importance to the patient, as the disease in these early stages is more tractable than later on. The symptoms which characterize this prodromal stage are the following: There is an appearance of a mist before the eye or eyes, and this mistiness may change in density. Rainbow colors are seen, especially in the shape of a ring around a candle flame. These rainbow-color rings do not touch the flame, but are separated from it by a dark space. The range of accommodation is reduced, and the eye appears prematurely presbyopic. This symptom is probably due to the hyperæmia of the ciliary body. In some cases the eye becomes myopic, which fact can be explained only by the assumption that the crystalline lens *in toto* is pressed forward toward the cornea, and that, in spite of the fact that in this manner the zonule of Zinn is stretched, and that an applanation of the lens is taking place. There is pain, which may be slight or even excruciating, and which is located in and around the eye, and in the forehead, the eyebrows, the cheek bones, the nose, and the temple. There is an increase of the intra-ocular pressure, which will manifest itself by an increase in the degree of tension of the eyeball; this increased tension varying from a barely perceptible to a stony hardness. The intra-ocular pressure is tested by directing the patient to look downward, then gently laying the tips of the forefingers upon the upper lid, and alternately pressing them upon the eyeball, as we do when we are searching for fluctuation elsewhere. By comparing the amount of impression we are able to make on a diseased eyeball with that which we can produce on its healthy fellow, or on the healthy eye of a third person, we can form an estimate of the increase of intra-ocular tension in the given case. According to the degree of hardness, we speak of it as $+$ T. (tension) $+ T_1$, $+ T_2$, and $+ T_3$. Several instruments (tonometers) have been invented to give an exact measurement, but they do not seem to be altogether reliable.

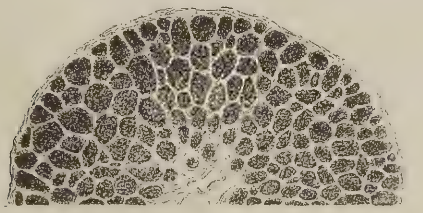

FIG. 2308.

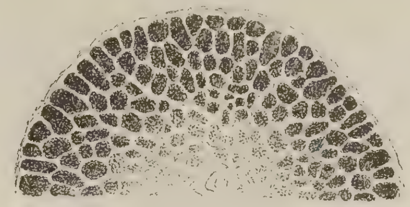

FIG. 2309.

The prodromal stage passes over into that of the *glaucoma evolutum* as soon as the visual acuity is lastingly reduced.

The *Glaucoma simplex acutum* is, if ever, very rarely observed. It would seem to have existed in a few cases in which sight was lost within a few hours without any inflammatory symptoms, and with barely increased pressure.

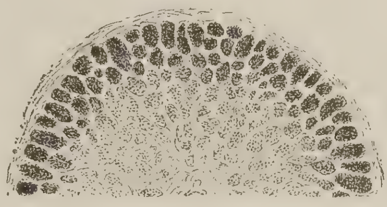

FIG. 2310.

Glaucoma simplex chronicum is characterized by the fact that externally the eye shows no marked signs of disease. The cornea, anterior chamber, iris, and pupil appear normal. The main symptoms are: the loss of vision, the excavation of the optic papilla, and the increase of the intra-ocular pressure. The latter symptom may, however, be imperceptible, or it may be present only at times.

An increase of the intra-ocular pressure is generally accepted to be the cause of the glaucomatous excavation of the optic papilla. The normal optic papilla has a central depression (physiological excavation) which may, in rare cases, reach so far toward the periphery of the optic papilla that at first sight it will strike the observer as a glaucomatous excavation. I have seen several cases in which the absence of all other symptoms alone convinced me of the fact that I was not dealing with a chronic glaucoma. Such a physiological excavation may have a sloping or a sharp edge, and may appear quite deep, yet it can never reach farther back than the anterior surface of the normal lamina cribrosa. In our judgment of the width as well as of the depth of such a physiological excavation we must take into consideration the fact that the optic nerve fibres, after they have passed through the lamina cribrosa, lose their marrow, become non-medullated, and are then diaphanous. Thus, a physiological excavation of the optic papilla is likely to appear much larger than it actually is. The illustrations, Figs. 2308, 2309, 2310, and 2311, will give a more palpable illustration of this fact. They are taken from specimens of a very short (hypermetropic) eye. Fig. 2308 is a transverse section taken from the optic nerve just behind the lamina cribrosa. Fig. 2309 is taken from near the anterior surface of the lamina cribrosa, and Fig. 2310 just from the anterior aspect of the lamina cribrosa. Fig. 2311 is a longitudinal section of the optic nerve entrance of the same eye.

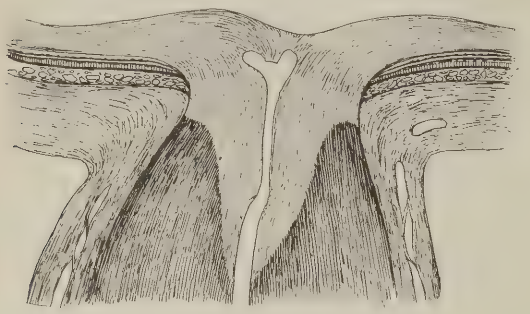

FIG. 2311.

The eye from which these specimens were taken probably showed during life an apparently very large physiological excavation, while the central (actual) excavation, caused by the manner in which the nerve fibres pass over into the retina, is only very slight. The condition illustrated by these drawings is chiefly found in hypermetropic eyes, while in myopic eyes the double-contoured nerve fibres reach farther forward and end in a straight, or even slightly convex, line.

If we now compare with this physiological excavation the typical glaucomatous excavation (see Fig. 2312), we find that here we have to deal with an actual and deep hollowing out of the optic papilla.

We furthermore see, in this figure, that the actual excavation has for its floor a thin layer of atrophic nerve fibres and the compressed lamina cribrosa. The nerve-fibre layer and the lamina cribrosa are together pressed out of the sclerotic, and behind it into the trunk of the optic nerve. The walls of the excavation are also lined with a very thin layer of atrophic nerve fibres. These fibres follow very closely in their course the indentations and projections of the surrounding scleral tissue, and finally pass over into the atrophied nerve-fibre layer of the retina.

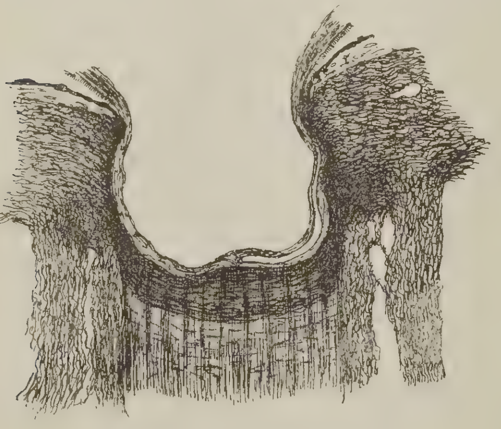

FIG. 2312.—Glaucomatous Excavation.

From the foregoing we understand that the physiological excavation in the normal eye may appear as having a sharp edge, but usually it has none, and cannot, for obvious reasons, reach to the periphery of the optic papilla; that the typical glaucomatous excavation, however, has always a sharp edge, and can reach to the very periphery of the optic papilla (when all nerve fibres are destroyed), and always comes very close to it. Moreover, in the typical glaucomatous excavation the lamina cribrosa is pressed backward and out of its normal position. It can, therefore, not well be confounded with a simple atrophic excavation, since this is always very shallow, and the lamina cribrosa is found in its normal position and of normal appearance.

By the aid of these anatomical facts we shall now easily understand the ophthalmoscopic picture of a glaucomatous excavation (see Fig. 2313).

The most striking phenomena of a glaucomatous excavation pertain to the retinal blood-vessels. Just before reaching the optic-nerve papilla these blood-vessels are seen to pass over a yellowish ring, which corresponds neither to the normal scleral nor to the normal connective-tissue ring as seen around the normal optic papilla. On the inner margin of this yellow ring the blood-vessels are seen to bend inward, then they disappear partially or altogether, and reappear dimly in the depth of the excavation, but in a parallactic displacement. If the excavation is very deep, it may be impossible to see those vessels which are located in the floor, while those which occupy the retinal portion are distinct, and *vice versa.* The depth of the excavation may thus be approximately measured by means of the glasses necessary to see the two portions distinctly.

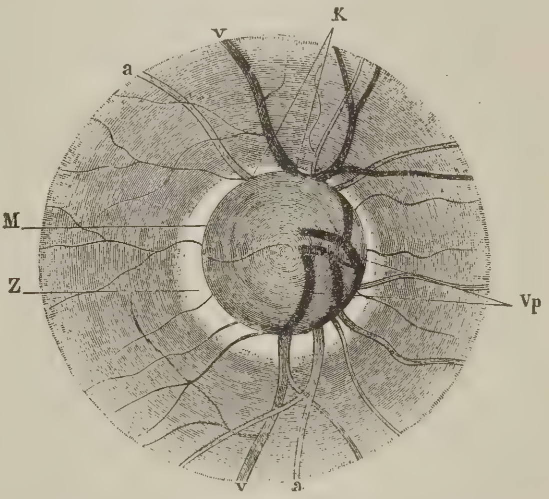

FIG. 2313.—Glaucomatous Excavation as Seen with the Ophthalmoscope. (From Edward von Jaeger.) *a, a,* Arteries; *v, v,* veins; *K,* points, on the border of the papilla, where the vessels make a sharp bend; *Vp,* portions of blood-vessels lying in the excavation; *M,* border of the excavation; *Z,* surrounding yellow zone.

The optic nerve forming the bottom of the excavation appears punctated. It has usually a white appearance in the centre, where it is directly illuminated, while the parts which are only indirectly illuminated appear bluish or greenish. By moving the mirror slightly the view may be changed in such a manner as to make a formerly greenish part appear whiter. The punctation is probably produced by the fact that the meshes of the anterior surface of the lamina cribrosa are visible on account of the atrophy of the nerve fibres.

The yellowish ring around the optic papilla, or at least what is left of it, is caused by an atrophic condition of the choroid, which is undoubtedly due to the stretching of this membrane during the development of the excavation, and is not due, as some authors maintain, to a chronic choroiditis.

A further vascular symptom is the spontaneous pulsation of the retinal arteries. This is but rarely seen in recent cases. It can frequently be produced by pressure on the eyeballs.

The gradual loss of sight (central visual acuity and visual field) is in a general way in proportion to the size and extent of the excavation of the optic papilla and the consequent atrophy of the optic nerve fibres. Nevertheless, a number of cases have been observed and reported in which an apparently large and deep excavation had not yet become associated with a great loss of vision. In some cases the central or paracentral vision will be destroyed before the periphery seems to be materially altered, and in other cases the loss of vision at first affects the peripheral vision alone. The contraction of the visual field begins frequently on the nasal side, and gradually extends upward and downward, so that in some cases at a certain stage a perfect hemianopia has been observed. Gradually the visual field grows smaller and smaller. It often has the shape of an ellipse with the point of fixation lying in the nasal focal point. This form of contraction of the visual field is pre-eminently found in glaucoma, while an actually concentrical limitation of the visual field is usually due to diseases of the optic nerve alone, or to retinitis pigmentosa with subsequent atrophy of the optic nerve.

All these symptoms are accompanied by a gradual diminution of the light sense. The color sense is usually well preserved, even when the visual field is reduced to almost nothing.

The loss of vision and the reduction of the light sense are the symptoms of glaucoma simplex which usually bring the patient to seek relief. Generally one eye is then already found to be badly affected, while the trouble is beginning in the second eye.

Glaucoma Inflammatorium Acutum.—The attack of acute inflammatory glaucoma comes on suddenly, and probably more frequently during the night than in the daytime. The pain, which is the most prominent symptom of this form of glaucoma, is often fairly excruciating. It is seated in the eyeball, the eyebrow, the forehead, and temple, and it may extend even to the occipital region. It may be combined, furthermore, with nausea and vomiting. There is usually a considerable secretion of tears and of watery fluid from the nose, and photophobia is likely to be present. These symptoms are, moreover, accompanied by some œdema of the eyelids, and especially of the upper one. Ayres has seen a case which was ushered in by intense chemosis. When the lids are separated the conjuntival blood-vessels are found to be considerably injected, and the bulbar conjunctiva to be slightly chemotic. The episcleral vessels around the cornea, too, are hyperæmic, and form a reddish-blue ring around the corneo-scleral margin. The anterior ciliary veins are distended and tortuous.

The cornea has a dead appearance, like glass which has been breathed upon. Under oblique illumination its surface appears irregular, as if pricked with a needle, and there may be slight deposits of fibrin on Descemet's membrane. If the cornea is touched with the end of a probe, a feather, or a thin roll of tissue paper, it is found to be almost anæsthetic, and the reflex contraction of the orbicularis muscle of the eyelids follows the insult long after it does so in a healthy eye. This anæsthesia may be noticeable over the whole area of the cornea or only in portions of it. By palpation the eye is found to be hard. This sudden increase of the intra-ocular pressure is the cause of the dimness as well as of the anæsthesia of the cornea.

The anterior chamber is shallow, the iris and crystalline lens being pressed forward toward the cornea. The pupil is wide, and reacts but very slightly under the stimulus of light. There may be some posterior synechiæ.

When the attempt is made to get an ophthalmoscopic view of the interior of the eyeball, it is often barely possible to see a reddish reflex, but no details of the fundus. This is due as well to the dimness of the cornea as to a diffuse opacity of the vitreous body.

Sight is considerably reduced, and it may be diminished to the bare perception of light. This symptom is most probably due to the pressure exerted upon the optic nerve fibres, the retina, and the retinal blood-vessels, and to the resulting paralysis of the nervous elements and ischæmia of the retina. That this is the correct explanation of the symptoms seems to be proven by the pulsation of the retinal arteries, the systole of the heart alone being able to overcome the intra-ocular pressure to some extent, and by the fact that a release of the pressure by operation will restore sight. The dimness of the cornea and the vitreous body, moreover, help to reduce the vision.

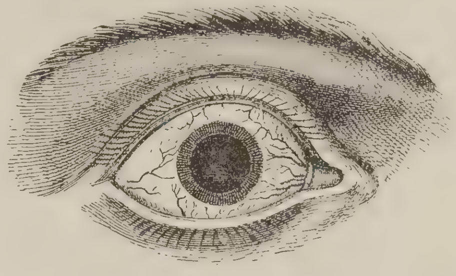

FIG. 2314.—Chronic Inflammatory Glaucoma. (After Schmidt.)

The attack of acute inflammatory glaucoma may last from a few hours to several weeks, and sight may again considerably improve as the attack passes over. Nevertheless, the eye, although it may look so, is no longer in the same condition as before the attack, and every new attack will leave it in a worse state. Repetitions of the attack are the rule. In the intervals between the attacks the anterior chamber remains usually shallow, the movements of the iris are restricted, and the tension remains somewhat increased. In other cases the acute stage passes directly over into the chronic one. When all these symptoms are less marked, the affection is called *glaucoma subacutum.*

There is, furthermore, a limited number of cases of acute glaucoma on record in which sight was absolutely destroyed during the first attack, and in the course of a few hours. These cases have been given the name of *glaucoma fulminans* (von Graefe).

Glaucoma Inflammatorium Chronicum.—In the chronic inflammatory form, which may follow an acute attack or begin with a chronic character, all of the glaucomatous symptoms are slowly developed, and the external inflammatory signs are less marked than in the acute form. The injection of the conjunctiva is there, but there is no œdema of this membrane, nor of the eyelids. The episcleral blood-vessels, and especially the anterior ciliary veins, are plainly visible and tortuous (see Fig. 2314). There is a marked injection of the deeper-seated blood-vessels around the corneo-scleral margin, and in the later stages the sclerotic tissue has a peculiar leaden appearance. The cornea may be perfectly clear, or it is slightly hazy, and it often shows minute superficial or even deeper points of ulceration. The anterior chamber is shallow and becomes more and more so as the disease advances; and the pupil, which is at first of medium size and acting sluggishly, soon undergoes an increasing degree of dilatation and becomes immovable. The iris tissue, at first swollen and discolored, will be found, at a later date, attenuated, and undergoes a slow process of atrophy. The intra-ocular pressure is increased above the normal, and there is a gradually increasing excavation of the optic papilla with a consequent atrophy of the optic nerve fibres.

The patients suffer at times from considerable pain and neuralgia, especially at night. The visual acuity, the visual field, and the light sense are gradually more and more reduced. This is the more noticeable after each exacerbation of the process.

The chronic inflammatory glaucoma seems to be the most frequent form in which this disease is observed. We must state here that the acute inflammatory, as well as the chronic inflammatory, variety may be preceded by a simple chronic glaucoma.

When the sight, through the effects produced by the glaucoma in one of its different forms, has been perfectly abolished, or at least to such a degree that merely the perception of light is retained, we speak of the condition as *glaucoma absolutum.* The progress of the disease, however, does not end here, and a further glaucomatous degeneration of the eyeball takes place. In some cases the eye is only at times painful and shows but slight external alterations, and the media remain for a long period in such a condition that an ophthalmoscopic examination can easily be made. In most cases, however, the increasing malnutrition leads to the formation of glaucomatous cataract. The anterior chamber becomes so shallow that the anterior lens capsule almost touches the posterior surface of the cornea, or actually does so. The eye remains painful, and the pain is at times very considerably exaggerated. Gradually ulceration of the cornea and the formation of scleral or corneal staphylomata may take place. The ulceration may lead to perforation and subsequent shrinking of the eyeball. All these symptoms may be accompanied by very annoying photopsiæ.

In the foregoing we have considered what is designated as primary glaucoma. We come now to the forms of secondary glaucoma.

Secondary glaucoma may appear in the shape of a simple or inflammatory glaucoma. It has been observed to follow various diseases of the eyeball. It may follow a diffuse or sclerosing keratitis, vesicular (bullous) keratitis, or that form which is known as ribbon-shaped keratitis; yet it is more frequently observed in cases of anterior synechia, with or without leucoma of the cornea.

Serous iritis and irido-choroiditis are apt to cause glaucomatous symptoms. Glaucoma may furthermore follow a plastic iritis when it has led to the formation of posterior synechiæ, and especially when a total circular synechia has been formed, whether this has led to the seclusion of the pupil alone, or to seclusion combined with occlusion of the pupil. But an occlusion of the pupil alone (which can, for instance, follow an operation for cataract extraction) may also be sufficient cause for the production of glaucoma.

Dislocation of the crystalline lens, or a too rapid swelling of the lens substance after the operation of discission or after an injury to the lens capsule, may lead to glaucoma. This is one of the bad results which often followed the old method of couching cataractous lenses.

Serous choroiditis, although leading more frequently to detachment of the retina, may give rise to glaucoma.

The most important one among the diseases of the retina which may be followed by glaucoma is the hemorrhagic retinitis (*glaucoma hæmorrhagicum*). In fact, hemorrhages into the retina from any cause may lead to hemorrhagic glaucoma. The pathological substrata are some form of disease of the blood-vessel walls, an inability of the filtration channels to carry off the corpuscular elements of the blood, and a consequent blocking up of these channels. Glaucoma has been furthermore observed in cases of pigmentary retinitis and of atrophy of the optic nerve. In these cases the occurrence of glaucoma was, however, probably a coincidence only, and it would seem to have been a primary glaucoma, not a secondary one.

Collins, Keyser, Buller, Knapp, and the writer have had occasion to see glaucoma follow cataract extractions and needle operations. In these cases the lens capsule or the vitreous body, with or without some part of the iris, was found to have blocked the filtration angle.

Secondary glaucoma is apt, furthermore, to occur in eyes suffering from staphyloma, and the increase of pressure then helps to the further increase of the staphyloma.

All intra-ocular tumors are likely to cause a glaucomatous condition of the eye during their growth.

Hydrophthalmus congenitus (cornea globosa; buphthalmus; keratoglobus) must probably be regarded as intra-uterine glaucoma.

Ayres saw a case of glaucoma caused by a very large nasal polypus. A cure was effected by the removal of this tumor.

The instillation of any and all mydriatics, even of one as weak as euphthalmin, may, under favorable circumstances, bring about an attack of acute glaucoma.

Diagnosis.—The differential diagnosis between glaucoma simplex chronicum and amblyopia caused by a simple atrophy of the optic nerve may be sometimes rather difficult, especially since there are cases of simple glaucoma in which there is no *appreciable* increase of the intra-ocular tension, and they may come under observation when as yet there is only a partial excavation of the optic papilla. This difficulty is to be met only by repeated careful examinations, until one of the necessary symptoms is marked enough to make the diagnosis secure. In this connection I may mention that the yellowish halo around the optic papilla which is characteristic of glaucoma, though little marked, seems to be but seldom wanting, and may therefore help in making the diagnosis. Furthermore, a simple atrophy of the optic nerve may at a comparatively early stage lead to diminution of the color sense, while glaucoma does not seem to interfere often with the color perception.

The diagnosis of an acute primary inflammatory glaucoma may appear plain from the condition of the eye when it comes under observation; yet the same general condition might also be a secondary one and due to an intra-ocular tumor. Here the position of the defect in the visual field, the usual absence of the perception of rainbow rings, and the gradual and continuous loss of vision which is likely to have preceded the glaucomatous condition under consideration, may help to the diagnosis of an intra-ocular tumor, even if it cannot be otherwise demonstrated. To distinguish between a hemorrhagic and a primary acute glaucoma will hardly be possible, except in cases in which the retinal hemorrhages had obscured vision very materially, or in which the observer has had occasion to see the occurrence of such hemorrhages previous to the glaucomatous attack. The acute glaucoma might, furthermore, be confounded with serous iritis. Yet, the deposits on Descemet's membrane which are so marked in this affection, the depth of the anterior chamber, and the low degree of injection of the visible external blood-vessels (there may be none at all) will usually make it possible to exclude a primary glaucoma in such cases.

Glaucomatous, as well as any other complicated, cataract may, of course, by a careless observer, be taken for an uncomplicated cataract.

The primary chronic inflammatory glaucoma cannot well be confounded with any other eye affection.

Glaucoma is observed in about one per cent. of all eye patients. It seems to be a little more prevalent among females than among males. It has been seen to occur in children as well as in old age. Yet the majority of the cases are observed after the fiftieth year of life has been reached, and it is very seldom seen before the twentieth. Although glaucoma may at first attack only one eye, it is the rule that it will sooner or later attack the fellow-eye. In this connection we may state that the attack in the second eye seems to be apt to make its appearance soon after the first one is operated upon.

In the relative frequency of their occurrence the chronic inflammatory glaucoma takes the first, the chronic simple glaucoma the second, the acute inflammatory glaucoma the third, and the (doubtful) acute simple glaucoma the last place. The disease is almost confined to eyes afflicted with hyperopia or hypermetropic astigmatism, although it is found also occasionally to appear in myopic eyes. Some authors maintain that there is an inherited tendency to glaucoma in some families.

Where there is a tendency to glaucoma, an attack may be brought on by an extraordinary straining of the eyes, by mental disturbances, by excesses of various kinds, by various diseases, by the stopping of habitual secretions, especially of the menstrual flow in the climacteric period in females, and, as stated, by the instillation of a mydriatic into the conjunctival sac.

Before considering the nature of this disease we will next see what data the anatomical examination of eyes afflicted with glaucoma gives us to build our theories upon.

PATHOLOGICAL ANATOMY.—The most interesting part of a glaucomatous eye has been for a long time the optic-nerve papilla, with its excavation. In a case which is not very far advanced, we find a comparatively shallow excavation, which is deepest usually in the centre, sometimes at one side (especially the temporal one). The bottom of this excavation lies behind the level of the choroid, and consists of a thin layer of nerve fibres. Nerve fibres are, furthermore, seen to line the walls of the excavation, and to join the retina at a more or less acute angle. The retinal blood-vessels lie within this nerve-fibre layer, and come, according to the stage of the disease, more or less close to the edge of the excavation. The fibres of the lamina cribrosa appear pressed closely together, so as to render this membrane thinner than in the normal eye, and the whole lamina is bulged outward. Its choroidal portion is no longer in distinct connection with the choroid. The small blood-vessels found in the normal eye in this region are reduced in numbers or wanting altogether, and the nerve fibres are atrophied. The retinal veins are usually hyperæmic. All these conditions are considerably exaggerated in an advanced case like the one from which Fig. 2312 was taken, yet I have never seen a glaucomatous excavation which had not, though ever so thin, a lining layer of nerve fibres.

The portions of the choroid and the retina which surround the excavation are drawn to some extent down into it and toward its axis, and the choroid is, even in the more recent cases, very thin and atrophic. It lacks blood-vessels, especially capillaries, its pigment cells have, in a certain measure, or altogether, disappeared, and the pigment molecules are found lying in the adjoining tissue of the sclerotic. This condition is undoubtedly the anatomical explanation of the glaucomatous halo. In some cases small foci of infiltration are found in this portion of the choroid.

The choroid in general shows an anæmic condition of the capillary layer; while the venæ vorticosæ are usually choked with blood. Atrophic patches are sometimes found in its periphery.

The retinal nerve-fibre layer in very advanced cases is atrophied, and the blood-vessels of this membrane are partially or altogether obliterated.

In more recent time (Knies) the interest of the examination has been centred especially on the condition of the iris angle. We find here, although not at all invariably, an adhesion between the periphery of the iris and the posterior surface of the cornea. Thus the spaces which in the normal human eye lie between the fibres of the ligamentum pectinatum, and correspond with the canal of Fontana, are partially or totally obliterated. In recent cases the tissue surrounding Leber's venous plexus (corneo-scleral tissue) is infiltrated with round cells, and the periphery of the iris, being pressed forward, comes in contact with Descemet's membrane, the endothelial coat of which begins to proliferate. In this way a small amount of new connective tissue is formed between Descemet's membrane and the periphery of the iris, and this glues the two together, thus causing the obliteration of the spaces of Fontana (see Fig. 2315).

It is doubtful whether this agglutination of the iris to Descemet's membrane is due alone to the increased intraocular pressure, or to the direct pressure (Weber, Brailey) of the swollen and hyperæmic ciliary bodies. According to Brailey, the blood-vessels of the ciliary region are found to be considerably dilated, and their walls are reduced in thickness. Later on, the ciliary bodies and muscles are found to be thin and atrophic, and the smaller blood-vessels are obliterated. Leber's plexus is found patent or closed. In other cases the iris angle is found to be quite large and not blocked by iris tissue. In such cases the filtration channels are filled with cell detritus and fibrin, and thus a stoppage results.

Cusco stated that the sclerotic coat is always thicker in glaucomatous eyes, and especially near the entrance of the optic nerve. Weichselbaum and others found the episcleral veins filled with blood, and dilated and surrounded by foci of round cells. In some cases a proliferation of the endothelial coat of the venæ verticosæ has been observed.

Ulrich examined pieces of the iris which he had excised from glaucomatous eyes when making an iridectomy. He found the tissue of the iris atrophied and thin, and lacking cellular elements. The blood-vessels were partially dilated, and the thickness of their walls was considerably reduced—a part of them (especially of the smaller ones) were totally obliterated.

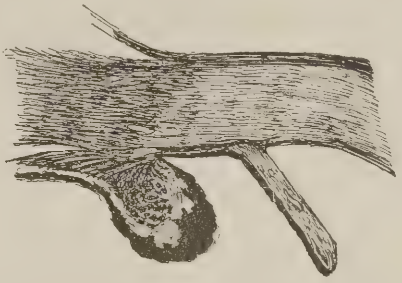

FIG. 2315.—Adhesion of Periphery of the Iris to Descemet's Membrane, causing Dilatation and Immobility of the Pupil, and Obliteration of the Iris Angle.

In some cases the vitreous body has been found detached. The cornea is usually œdematous.

It will be seen from the foregoing remarks that our knowledge of the pathological anatomy of glaucoma is as yet very meagre. This is the more astonishing, as a great many able workers have devoted considerable study to this interesting, and as yet mysterious, disease. Glaucoma, or at least a similar condition, has been experimentally produced in animals by ligating the venæ vorticosæ, by burning the corneo-scleral margin (Schoeler), and by injecting oil into the anterior chamber (Weber).

It is therefore evident that even to this day it has been impossible to find a common cause for all the different forms of affections which produce the increase of intraocular pressure, as well as the gradual destruction of vision, combined with an excavation of the optic nerve, —in brief, for the disease which we call glaucoma. Consequently, it is not to be wondered at that the number of theories constructed for the explanation of the nature and seat of glaucoma is legion. These theories may be classed under three heads: those which make the increase of the intra-ocular pressure the main feature; the theories which deal with the disease as originally due to a strange affection of the optic nerve; and, finally, those which seek the cause in an inflammation of the choroid.

THEORIES PUT FORWARD IN EXPLANATION OF THE DISEASE.—The theories making the increased intra-ocular pressure the main feature attribute it to a hypersecretion into the vitreous body, consequent upon an active but somewhat atypical inflammatory process in the choroid; or they consider it due to an irritation of the secretory nerves; or the increase in pressure is thought to be the result of reduced facilities of excretion from the eyeball, or of stasis of the venous blood (passive hypersecretion, Mauthner).

Von Graefe thought that glaucoma was a choroiditis or an irido-choroiditis, with diffuse imbibition of the vitreous body—processes which would lead to an increase in volume of the vitreous body, and consequently to increased intra-ocular pressure. Later on, he thought this choroiditis to be due to an irritation of the secretory nerves. Arlt and Sattler adhere to the former theory. The latter found inflammatory changes in the choroid, but his description of these changes is such that it seems hardly possible to attribute a disease of the character of glaucoma to so slight a cause. If this explanation were correct, why, it may be asked, is not a glaucoma produced in every case, or at least in the majority of cases, by an exudative choroiditis?

The neurotic theory has been put forth by Donders. He says that in glaucoma chronicum simplex we have no signs of an inflammatory character, and, furthermore, the increase of pressure has always preceded the inflammatory symptoms where they exist. The cause of the increased pressure must, therefore, lie in the irritation of secretory nerves. Von Graefe, as stated before, partially adopted this theory; but he characterized even the glaucoma chronicum simplex as an inflammatory condition. Schnabel, who also supports the neurotic theory, refuses to acknowledge the inflammatory character of any form of glaucoma. He claims that the glaucomatous ophthalmia is simply a neuralgia of the sensory nerves, while the increased pressure is due to a neuralgia of the secretory nerves of the eye. Glaucomatous ophthalmia, then, and anomaly of pressure, spring from the same root.

The cause of the secretory neurosis is found in the atrophy of the ciliary processes and the consequent enlargement of the diameter of the circle formed by these processes, which enlargement causes an increased tension of the suspensory ligament of the crystalline lens.

The intra-ocular irritation of the secretory nerves lies, therefore, in the anterior part of the eyeball, the iris, and the ciliary body (Donders, Schnabel, Roeder), and is a reflex neurosis.

It might, however, with the same right be claimed that it is an extra-ocular affection which brings about such a reflex neurosis, and thus Hutchinson and Schmidt-Rimpler have considered a neuralgia of the trigeminus nerve as the cause of glaucoma. Mooren finds the cause in affections of the brain or spinal medulla.

Weill has formulated and elaborated a theory in which he tries to prove that all the symptoms of glaucoma are due to irritation of the sympathetic nerve.

The most plausible theories yet advanced are those which refer the cause of glaucoma to mechanical obstructions to the drainage of the fluids from the eyeball, either by obliteration of the lymphatic channels in the iris angle and, perhaps, in the optic nerve, or by obstruction of the reflux of the venous blood from the eyeball. Such obstructions must undoubtedly cause an increase of intra-ocular pressure, if at the same time the afflux remains the same.

The present status of our knowledge of the course of the nutritive fluids of the eyeball is chiefly due to the labors of Knies. He found that the fluids are secreted by the choroid, ciliary body, and iris. The fluids coming from the chorio-capillary layer take their course through the retina into the vitreous body, then forward toward the crystalline lens. While a portion of these fluids now penetrates the equatorial portion of the lens, the larger quantity goes through the suspensory ligament and around and through (Ulrich) the iris into the anterior chamber. The aqueous humor is secreted by the anterior portion of the ciliary body and the iris. In the normal eye no fluid is secreted through the cornea (Leber), or, if any is secreted, the quantity is very small. The way by which the largest portion of the aqueous humor leaves the eyeball is through the iris angle; here it goes partially into Leber's venous plexus and partially into the lymph canals of the conjunctival and episcleral tissue, and of Tenon's space.

It seems, therefore, evident that an obstruction of the excretory canals will cause glaucoma. Such an obstruction may be due to an inflammation in the iris angle, which, as we saw, brings about an actual adhesion between Descemet's membrane and the periphery of the iris, with or without obliteration of Leber's venous plexus (Knies); or it may be due to entanglement of cell detritus in the meshes of the ligamentum pectinatum; or, finally, it may be due simply to the swelling of the ciliary processes, which will press the periphery of the iris against the corneo-scleral tissue (Priestley-Smith, Brailey, Weber). According to Priestley-Smith the size of the lens is, so to speak, too large for the eye in most cases. Thus accommodative strain may crowd the iris periphery against the cornea. Furthermore, the obstruction may be caused by the atrophy of the iris tissue and the consequent obliteration of the channel by which, in the normal eye, fluids pass directly through the iris (Ulrich). Some authors speak of an obliteration of the lymph canals near and in the optic-nerve entrance as the partial cause of glaucoma. Gifford has shown that there is a current backward in the lymph spaces accompanying the central retinal vessels.

The obstruction of the reflux of the venous blood from the eyeball may be due to an increased rigidity of the sclerotic (Stellwag, Arlt); to inflammation and consequent increased thickness of the sclerotic (Cusco); to fatty degeneration of the sclerotic (Coccius), all of which pathological changes will tend to compress the venous blood-vessels. Magni finds that the ciliary nerves are atrophic in cases of glaucoma. This atrophy of the ciliary nerves causes shrinking of the vitreous body and sclerotic, and stasis in the venous blood-vessels. This stasis, according to others, may be due to an infiltration of the tissue surrounding the veins, or to a proliferation of their endothelial coat.

All of these theories take glaucoma to be a disease due to a reduction of the area of the channels of excretion, and they consider all other symptoms of the disease, including inflammatory attacks, anæsthesia of the cornea, and excavation of the optic papilla, to be directly dependent on the increased intra-ocular pressure.

Most recently Schoen has advanced a new theory of glaucoma, which also refers the cause of the disease to mechanical conditions of the eyeball. Although it does not strictly belong among the "pressure theories," it may find its place here. He says that an overstrain of the accommodation is the etiological momentum in the development of all cases of primary glaucoma. This may act in two ways: by pulling the sheaths of the optic nerve forward (thus causing excavation), and by pressing the crystalline lens forward (thus producing glaucomatous increase of pressure). As long as all the fibres of the ciliary muscles act, glaucoma simplex will follow this overstrain. When the inner fibres of the ciliary muscles become insufficient as compared with the outer ones, the lens is pushed forward, and glaucoma, with increased pressure, is the result. The two modes can act combinedly in various ways. The pathological changes found in the ciliary body are due to subsequent inflammation.

The theories which consider glaucoma due to an affection of the optic nerve were inaugurated by Jaeger. He sees the direct cause of the disease in changes in the ring of blood-vessels which bring blood to the portion of the sclerotic surrounding the optic-nerve entrance, to the lamina cribrosa, and to the optic papilla (Haller's ring). He denies that the increased intra-ocular pressure is characteristic of the glaucomatous process, although it is an important symptom. Schnabel and Klein support this theory.

The theories which take glaucoma to be the result of a choroiditis, and assume that this choroiditis alone (without increase of pressure) would lead to the loss of function and excavation of the optic papilla, have found their most urgent advocate recently in Mauthner. He says: Glaucoma is an inflammatory process in the system of the ciliary blood-vessels,—a process which may concern the whole area of this system, or leave some portions of it free; an inflammatory process which (with the exception of the location of the glaucomatous halo) is distinct from others by the lack of formed elements in its products, and by the faculty of inducing a rapid atrophic process in the tissues involved. This inflammation is often combined with an increase of the intra-ocular pressure. This is less marked when the inflammation concerns only the area of the short posterior ciliary arteries that go to the choroid, but is hardly wanting whenever the area of the anterior ciliary arteries and long posterior ciliary arteries (ciliary body, iris, and cornea) is attacked; in this latter case the fluid secreted into the vitreous body is exuded from the inflamed ciliary body (Brailey). The increased intra-ocular pressure is not a constant symptom, and it is not the source of the functional trouble. This latter is caused by the fact that the inflammatory process of the choroid exerts its action upon the neighboring layer of the retina (the rods and cones) while the affection of the optic papilla, characteristic of glaucoma and due to the inflammation in the area of the arterial scleral ring, plays only a secondary or final rôle in the total ruin of vision.

When the glaucomatous inflammation suddenly attacks the area of the long posterior and anterior ciliary arteries (a kind of kerato-irido-cyclitis), we have the acute inflammatory glaucoma. The disturbance of vision is only proportionate to the dimness of the media; the function of the retina does not suffer from the sudden increase of the intra-ocular pressure. In exceptional cases the uveitis, which is the glaucoma, will suddenly attack the *whole* area of the ciliary blood-vessels; the attack, then, of course, includes the choroid. The function of the rods and cones may be thus suddenly (and usually forever) destroyed by the exudation; this is the case in glaucoma fulminans; or these organs may at least suffer considerably and lastingly; this is the case in glaucoma acutum inflammatorium.

Whenever the inflammatory process creeps slowly and in a chronic manner from in front backward, or *vice versa*, we have the glaucoma chronicum inflammatorium. In the former case the excavation will be developed at a late period only, while in the latter case the excavation will exist before any inflammatory changes appear in the anterior portion of the eyeball.

When the affection is a chronic choroiditis posterior, we have the glaucoma chronicum simplex; and the glaucoma acutum simplex is that rare form in which this posterior choroiditis appears acutely; a form of glaucoma, however, which is very soon followed by the anterior choroiditis in such a manner that the painless increase of intra-ocular pressure and blindness are soon succeeded by inflammatory changes in the anterior portion of the eyeball.

The writer may here state that it seems to him impossible to adopt such a theory, as the choroiditis on which it hinges does not seem to exist. Careful examinations of many glaucomatous eyeballs have not revealed the presence of inflammatory changes in the choroid which would be important enough to be taken as a cause of the series of symptoms constituting the disease which we call glaucoma. It seems to the writer that the theories which seek the cause of glaucoma in a mechanical obstruction of the outlets of blood and lymph fluids from the eyeball are the most plausible ones, and there can, it seems, be no doubt but that a number of different influences may bring about such an obstruction. That the once increased pressure can easily cause an excavation of the optic papilla in hyperopic eyes, at least, seems to be plain from Figs. 2308, 2309, 2310, and 2311.

In more recent years Richey and a number of followers have again brought forward an older theory, according to which glaucoma is said to be the result of uric-acid diathesis, and they seem to have strengthened their views by numerous observations of improvements and cures by careful treatment of the lithæmia.

Prognosis.—The prognosis of glaucoma, unless its progress is interfered with by therapeutical or operative measures, is absolutely bad.

Treatment.—In the medical treatment of glaucoma an important step forward has been made since the myotics, and especially the sulphate of eserine (physostigmine, Laqueur) and the muriate of pilocarpine have been found to reduce the intra-ocular pressure. The value of these remedies in glaucoma is, however, a rather limited one. They do not and cannot cure glaucoma, but by their tension-diminishing influence they act beneficially during the prodromal stage, and they may well serve to stave off a threatening attack of glaucoma. By the forcible contraction of the sphincter pupillæ, induced by the action of these remedies, the periphery of the iris is, as long as this is yet possible, pulled away from the ligamentum pectinatum and thus its obstruction may be partially or even totally abolished for the time being. These remedies are, furthermore, of value before and after an operation for this disease. When instilled into the eye they generally also ease the pain of an inflammatory attack.

A cure of glaucoma or, at least, an arrest of the process, is to be accomplished only by operative measures. Among these the iridectomy (von Graefe) as yet holds the first place. Its value is greatest in the acute inflammatory and then in the chronic inflammatory forms, least in the chronic simple glaucoma. An early iridectomy in a case of acute inflammatory glaucoma is likely to bring vision again up to the normal. If performed at a later stage it may not be able to restore more than a part, or even nothing, of the lost vision. In the chronic inflammatory form the iridectomy usually restores a part of the lost vision; the quantity of this, however, depends very much upon what pathological changes the optic papilla and the nerve fibres had already undergone at the time of the operation. In the chronic simple glaucoma the iridectomy generally arrests the progress of the disease, and may produce an improvement of vision, although it does so but rarely. On general principles we may state that the earlier the operation is performed the greater may we expect its effect to be.

It is as yet an unsettled question why an iridectomy will lastingly reduce the intra-ocular pressure, although the fact is undoubted. It seems to be most likely that the explanation lies in the fact that the removal of a piece of iris tissue not only lessens the quantity of the blood-vessels, and, therefore, of blood within the eyeball, but also takes away a part of the obstacle to the draining of the fluids from the anterior chamber. It has been stated by Exner that a direct communication between the arteries and veins, without intervening capillary network, would take place in the parts of the iris directly wounded by the iridectomy. The writer, when reporting his studies on the process of healing after an iridectomy, had occasion to state that he had never been able to see such a condition. Arlt, in his recent book on glaucoma, takes pains to say that the writer's statements in regard to this question are of no value, since he had not injected the blood-vessels. The writer's paper on the question, however, states plainly that he injected most of the animals experimented upon with Berlin blue, and for the truth of the matter it is necessary to state here again that he was, and is to this day, unable to verify Exner's observations.

A number of authors maintain that the scar in the corneo-scleral tissue is of more importance even than the excision of a piece of iris tissue (Wecker), and they consider this scar a means of continued filtration of fluids from the anterior chamber. No direct proof for this opinion has thus far been given, but there is no doubt that scar-tissue, when consolidated, is, as a rule, more compact than normal tissue. It would, therefore, seem that we have a right to expect an effect just opposite to the one here given as an explanation of the action of an iridectomy in glaucoma.

Whatever the explanation of the healing influence of an iridectomy in glaucoma may be, one thing is certain, that we have occasion to see cases in which a typically and *lege-artem* performed iridectomy has not been able to stay the progress of glaucoma, as well as cases in which a very imperfect operation has had the desired effect. This would seem to show that science will some day find a procedure which will supersede the empirical operation of iridectomy for glaucoma. At present, however, it is as yet the safest and the most satisfactory measure in our hands.

Based on the theory that the corneo-scleral or scleral incision necessary to perform an iridectomy was the main feature of this operation in glaucoma, and that the excision of a piece of iris tissue was wholly unimportant to the end in view, besides, of course, having other disagreeable features (Quaglino, Wecker, and others), simple sclerotomy, and either anterior sclerotomy or posterior sclerotomy have been proposed and introduced in place of iridectomy. The efforts which have been made to supersede the iridectomy by the sclerotomy have, however, failed. This failure is not only due to the danger arising from prolapse or from incarceration of the periphery of the iris in the corneo-scleral wound, but also to the fact that the combined experience of many observers has shown that this operation is insufficient, and especially so in the inflammatory forms of glaucoma. It may be performed with more success in chronic simple glaucoma, and in cases in which an iridectomy has not been able to cut short the progress of the disease altogether, and in which a second iridectomy has by some authors been advocated. It may, furthermore, be considered of value in cases of glaucoma absolutum, when the pathological changes of the iris tissue no longer allow of the performance of an iridectomy.

Several authors have tried to replace iridectomy by an operation which aims at cutting the ciliary muscle (Hancock) or the tendinous portion at its insertion into the corneo-scleral tissue. These procedures seem not only to be of doubtful value, but also to be fraught with danger from subsequent sympathetic ophthalmia. The latter objection has, however, also been urged against sclerotomy. The most recent procedure is excision of the superior cervical sympathetic ganglion as introduced by Jonnesco. This operation is still *sub judice*, having its ardent admirers as well as enemies. A careful critical paper on the subject by Ziehe and Axenfeld says that in all cases of glaucoma in which our present therapeutic measures have not sufficed, the extirpation of the cervical sympathetic is a justifiable and advisable experiment, although it does by no means afford help in every instance.

Aside from the operation, the general condition of a patient suffering from glaucoma ought to be attended to. He ought to be especially restrained from everything which may in his case be apt to act as an occasional cause for a glaucomatous attack. If there is—and this is the rule—an error of refraction or accommodation, or of both, it must be corrected. In fact it is claimed that careful attention to refractive errors as practised in this country has reduced the number of cases of glaucoma.

Glaucoma not always being easy to recognize, it will be always well to examine carefully, with regard to the possible presence of this disease, every patient who comes to his physician complaining of, and seeking relief from, neuralgia of the eye and head, combined with obscurations of sight and with nausea. *Adolf Alt.*

GLECHOMA. See *Labiatæ.*

GLEN ALPINE MINERAL SPRINGS.—El Dorado County, California. Back in the mountain fastnesses at a distance of seven miles from Lake Sahoe, and at an elevation of 6,700 feet above the sea-level, are Gilmore's Glen Alpine Mineral Springs and Health Resort. The wild, rugged gorge in which they are situated runs back from Sahoe a distance of some ten miles. It is diversified throughout its length with varied scenes of beauty and grandeur, and terminates abruptly in a glacial amphitheatre. The region is rich in exquisite flowers and ferns. "Those dimpling lakes, with the wild beauty of their surroundings are sufficient to enthrall the heart of him who visits them; but if he be devoted to the rod and reel he will find an additional charm in the swarms of speckled beauties which sport in the clear depths and rise to the glancing fly."

This region has been opened to the public with great labor and expense by the construction of a wagon road as far as Glen Alpine Springs, and mountain trails to all the lakes, including a path for the ascent of Mount Sallac, which rears its head 10,000 feet above the level of the sea, and commands a wide and magnificent view of the distant peaks and numerous lakes. Good accommodations for guests will now be found at Glen Alpine Springs. Analysis by Dr. Anderson:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	21.17
Sodium carbonate	32.75
Potassium carbonate	Trace.
Magnesium carbonate	9.96
Calcium carbonate	45.09
Calcium sulphate	4.10
Ferrous carbonate	1.80
Alumina	1.43
Borates	Trace.
Silica	2.50
Organic matter	Trace.
Total solids	118.80

Free carbonic acid gas, 138.36 cubic inches.
Temperature of water, 39.6° F.

The water is very palatable and sparkling. Its action is gently aperient and diuretic, and the water is useful in dyspepsia and torpidity of the bowels as well as in renal and cystic disorders. It contains sufficient iron to give it important properties as a ferruginous tonic. *James K. Crook.*

GLEN ALPINE SPRINGS.—Sevier County, Tenn.

POST-OFFICE.—Newport, Cocke County. Hotel.

ACCESS.—Viâ Southern Railroad to Newport, Cocke County, thence by stage 12 miles west to springs.

These springs are located in a mountainous region, 3,000 feet above the sea-level. The usual charming scenery and exhilarating climate of the East Tennessee mountain district will be found here. The springs are four in number, and yield about sixty gallons each per hour. No analysis has been made, but the water is said to be chalybeate and very serviceable in debilitated and anæmic states, especially those arising from disorders of digestion and assimilation. Hay-fever patients are said to improve rapidly as a result of a sojourn at these springs. The improvements at the resort are by no means elaborate at present, but the location offers many attractions during the summer months to persons not afraid to grow strong by roughing it. *James K. Crook.*

GLEN SPRINGS.—Schuyler County, New York.

POST-OFFICE.—Watkins. Hotel and sanitarium.

ACCESS.—Watkins is situated on the Northern Central Railroad, between Elmira and Rochester. This road (a division of the Pennsylvania system) runs from Rochester to Baltimore, Philadelphia, and Washington. It connects at Rochester with the New York Central, West Shore, Michigan Central and other railroads, at Canandaigua with the Auburn branch of the New York Central, and at Elmira with the Erie and the Delaware, Lackawanna and Western Railroad. The Fall Brook Railroad also has a depot one mile and a half from Watkins. This beautiful and modern health resort and watering-place stands upon a broad plateau 300 feet above Seneca Lake, whose winding course it overlooks for nearly thirty miles. It is surrounded by pine forests and backed by an amphitheatre of hills rising in regular terraces to nearly 1,500 feet. At the foot of the hill, less than a quarter of a mile away, lies the village of Watkins, with its churches, shady streets, and lovely homes, while the entrance to the famous Watkins Glen and the landing of the Seneca Lake steamers are both within seven minutes' easy walking distance. Seneca Lake is one of the most remarkable bodies of water known. It is fed by deep springs, and has been frozen over only twice during the last century. For beauty of scenery and richness of coloring it has no superior, its shores are grand and picturesque, the sides thickly wooded in places, in others covered with fruit orchards and vineyards. This great body of water, nearly forty miles long and from two to four miles in width, exerts an unquestioned modifying influence on the atmosphere, tempering it in winter and cooling and freshening it in summer. A remarkable feature of this region is the great number of its sunny days during the fall, winter, and spring. The record for 365 days has shown that there were only 55 cloudy days, and 17 of those were in May. These features tend to make the location a very desirable winter as well as summer resort. The Glen Springs Park comprises sixty acres of woodland and lawn, about equally divided, and one can wander for miles over well-built walks, obtaining from almost every point grand and beautiful vistas of lawn, lake, forest, and glen. Within the park are bowling-alleys, tennis courts, croquet grounds, and golf links. Pleasant drives abound in every direction, while to those who prefer the water the fine, large steamers of the Seneca Lake Navigation Company, plying six times a day between Geneva and Watkins, afford every comfort and luxury. Good fishing is found in Seneca Lake, and within easy driving distance over good roads one can reach Keuka, Lamoka, Cayuta, and Little Lakes, all famous fishing resorts. The main building of the Glen Springs sanitarium, heated by steam and lighted by electricity and gas, consists of four stories and a basement, constructed in a substantial manner of brick and stone. The annex, a new building, has accommodations for one hundred guests. The two buildings are connected by a wide corridor enclosed in glass and heated in cold weather by steam. It affords ample space for exercise, and forms an excellent solarium during the winter months. These buildings are provided with all modern comforts and luxuries. On the grounds there are several large mineral springs which are used for drinking and bathing. The following analyses of the first four springs were made by Prof. S. A. Lattimore, of the University of Rochester. The fifth spring was analyzed by Prof. Charles F. Chandler.

Seneca Spring—Calcic.

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	9.90
Calcium sulphate	.47
Magnesium carbonate	2.10
Sodium chloride	.12
Silica	.07
Iron oxide	Trace.
Total	12.66

The water is entirely free from organic matter. This spring is situated two hundred feet higher than the buildings. It flows about 4,000 gallons of water per hour, and is used in the buildings for general domestic purposes.

Vulcan Spring—Alkaline-Saline, Chalybeate.

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	29.80
Magnesium carbonate	11.37
Iron carbonate	1.87
Sodium chloride	149.06
Alumina	Trace.
Silica	Trace.
Total	192.10

Carbonic acid gas, large quantities.

This is a clear, sparkling water, and issues from the rocks at a depth of 100 feet. It resembles the waters of Kissingen, and has diuretic, tonic, mildly aperient, and slightly alterative properties.

Salubria Spring—Muriated-Saline.

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	196.28
Calcium carbonate	19.68
Magnesium carbonate	.05
Silica	Trace.
Total	216.01

This spring issues from the rock at a depth of 250 feet, and resembles the class known in Germany as muriated (chloride of sodium) alkaline springs. It is somewhat similar to the waters of Vichy, Sachingen, and Bilin, but is more like those of Kissingen, Homburg, and Wiesbaden. The water has a stimulating effect upon the mucous membrane of the stomach and bowels and increases the flow of gastric juice and bile and promotes digestion and absorption. It has about the proper quantity of sodium chloride favorably to influence the process of osmosis. In large doses it is purgative.

Neptune Spring—Saline, Calcic, Iodo-bromated.

One United States Gallon Contains:

Solids.	Grains.
Calcium chloride	3,499.08
Magnesium chloride	635.67
Sodium chloride	6,368.33
Sodium iodide	Trace.
Sodium bromide	Trace.
Iron and alumina	Trace.
Total	10,503.08

This water constitutes a strong brine. It is quite remarkable for its large proportion of calcium chloride and its total freedom from calcium sulphate (gypsum). In its principal ingredients it resembles the brine springs of Michigan and the springs of Nauheim, Rehme, and Jaxtfelt. It may be classed as an iodo-bromated saline spring, and while not adapted for drinking purposes, is of great value for bathing. By charging the water with carbonic acid gas it becomes very similar to the Nauheim waters, and the treatment of glandular and rheumatic troubles, gout, lumbago, and sciatica, as well as the Schott method in chronic diseases of the heart, is carried out at Glen Springs. This water is also employed in the electro-chemical and electro-vapor baths, douches, sprays, etc. The spring is said to have its origin about 1,700 feet below the surface of the earth.

Deer Lick Spring—Alkaline, Saline, Chalybeate.

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	114.75
Potassium chloride	.23
Sodium bromide	.59
Sodium iodide	.04
Potassium sulphate	Traces.
Lithium bicarbonate	Traces.
Ammonium bicarbonate	1.08
Iron bicarbonate	1.73
Calcium bicarbonate	41.77
Magnesium bicarbonate	19.28
Alumina	.34
Sodium phosphate	Traces.
Silica	.64
Total	180.45

This water is clear and sparkling, without odor, and with a slightly astringent, mildly saline taste. Containing, as it does, besides chloride of sodium and iron, the rare ingredients of iodine and bromine (in combination), it may be ranked as a ferro-iodo-bromo-muriated spring. It is also rich in carbonic acid gas. It resembles in many respects the waters of Kreuznach, Hall, Duerkheim, and Krauenheit. It is an excellent drinking-water and, unlike many of the foreign iodo-bromated waters, may be taken as it flows without dilution. The Deer Lick water possesses tonic, alterative, diuretic, and mildly aperient properties. Tissue metabolism is promoted and the red globules of the blood are increased. Its physiological action fits it for use in anæmia, neurasthenia, chronic renal diseases, glycosuria, and chronic diseases of the uterus.

James K. Crook.

GLEN SUMMIT SPRINGS. — Post-Office. — Glen Summit, Luzerne County, Pennsylvania. Hotel.

Access.—Viâ Lehigh Valley Railroad, about 150 miles from New York and 125 miles from Philadelphia.

This attractive summer resort is on the summit of the

Nescopic Mountain, 2,000 feet above tide-water. The romantic scenery of the surrounding country and its easy accessibility, coupled with an excellent modern hotel furnished with all the recent improvements, have of late years served to bring the place into well-deserved prominence. The charming surroundings and pure, invigorating mountain air offer an enticing refuge from the toils and cares of city life during the hot weather. Numerous cases are cited of the apparent complete arrest of incipient lung disease after a few weeks spent here. The springs about Glen Summit are of the ascending variety, welling up along the lines of jointing in the Catskill formation from far down in the subterranean recesses below. The temperature of the water is acquired from the rocks at depths sufficient to be beyond the influence of surface temperatures, and is cold enough to cause an unpleasant chill to the hands when submerged for a few seconds. An examination, however, will show that these waters owe their value rather to their purity and palatability than to their chemical ingredients. The following analysis was made by Prof. W. H. Dean, chemist, of Wilkesbarre, in 1896:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	0.23
Calcium sulphate	.20
Calcium carbonate	.20
Silica	.11
Iron oxide and alumina	.03
Free ammonia Nitrogen as nitrates Nitrogen as nitrites Albuminoid ammonia	.00
Loss on ignition	.33
Total	1.10

This shows a very pure and valuable water for domestic uses. Among other excellent pure-water springs in the neighborhood are the "Great Indian" Spring, yielding over 4,000 gallons hourly (if supplies the hotel); the "Twin" Springs, the "Bear" Spring, and the "Counterfeiter's" Spring. There are also other springs which have not been named. *James K. Crook.*

GLENN SPRING.—Tipton County, Tennessee.

POST-OFFICE.—Atoka. Cottages.

ACCESS.—Viâ Chesapeake, Ohio, and Southwestern Railroad (Mississippi Valley route) to Atoka; thence seven miles to springs.

This spring is situated under the shadow of Chickasaw Hills. It has quite an ancient reputation in Western Tennessee in the treatment of liver, kidney, and digestive disturbances. The spring is surrounded by a magnificent grove of trees, which lends a romantic charm to the neighborhood. It yields about ninety gallons of water per hour. The following analysis was made in 1880 by W. S. Lupton, analytical chemist:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium carbonate	1.58
Calcium carbonate	9.64
Magnesium carbonate	7.10
Potassium carbonate	.05
Iron carbonate	.54
Potassium sulphate	.27
Calcium phosphate	.01
Sodium chloride	.16
Silica	1.38
Total	20.73

Carbonic acid gas, 14.64 cubic inches.

This is a very good antacid and mild diuretic water with ferruginous properties. *James K. Crook.*

GLENN SPRINGS.—Spartanburg County, South Carolina.

POST-OFFICE.—Glenn Springs. Hotel and cottages.

ACCESS.—From Spartanburg, a distance of 12 miles by the Glenn Springs Railroad; double daily service.

These springs are located in a charming section of the country, broken by granite and sandstone hills. The elevation is about 1,000 feet above the sea-level. Many improvements have recently been added, the hotel having been greatly enlarged and comfortable cottages built. Many additional improvements are under way, and when completed Glenn Springs will bid fair to compete with the leading spas of the country. The following analysis of the Glenn Springs water was made in 1880 by C. U. Shepherd, Jr.:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Magnesium carbonate	3.32
Calcium sulphate	91.50
Sodium chloride	2.21
Potassium chloride	.52
Total	97.55

This analysis is probably incomplete. We are informed that a more recent partial examination of the water showed the presence of lithia in considerable quantities. The water has been in use many years. Numerous well-known physicians of South Carolina attest to its virtues, especially in disorders of the alimentary tract, dyspepsia, diarrhœa, dysentery, hemorrhoids, etc. It is said to be very useful in functional uterine affections, dysmenorrhœa, amenorrhœa, leucorrhœa, etc., as well as in torpidity of the liver and biliousness. *James K. Crook.*

GLENOLA SPRINGS.—(Formerly Wayland Springs) Nottoway County, Virginia.

POST-OFFICE.—Jennings Ordinary. No accommodations at present. These springs are located in a fine undulating stretch of country, half a mile from Jennings Ordinary, on the Southern Railroad, and six miles from Burkeville Junction on the Norfolk and Western Railroad. The location is about 500 feet above the sea-level, and the climatic conditions are of a very desirable character. The average summer temperature range is 77° F., winter 38° F. The temperature of the water is 48° F. There are several springs in the neighborhood, only one of which has been chemically examined. The following analysis was made by Prof. M. B. Hardin, of the Virginia Military Institute:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium carbonate	0.55
Lithium carbonate	.01
Magnesium carbonate	.26
Calcium carbonate	.70
Strontium carbonate	.03
Iron carbonate	.06
Manganese carbonate	Traces.
Potassium sulphate	.05
Potassium chloride	.09
Sodium chloride	.34
Sodium iodide	Traces.
Sodium nitrate	.11
Sodium phosphate	.01
Aluminum phosphate	.04
Ammonium nitrate	Traces.
Silica	1.92
Aluminum silicate	.20
Calcium fluoride (suspended)	Trace.
Titanium dioxide	"
Organic matter	"
Carbonic acid in the bicarbonates	.71
Total	5.08

Carbonic acid gas, 6.65 cubic inches.

This water is distinguished by the presence, in small but perceptible quantities, of the iodide of sodium. It may be ranked as an iodic-alkaline-carbonated water. The spring yields about thirty-eight gallons per hour the year round. Since its discovery, in 1883, it has been extensively used in cases of rheumatism, dyspepsia, and renal diseases. The location offers excellent advantages as a health resort. *James K. Crook.*

GLENWOOD SPRINGS.—Garfield County, Colorado.

POST-OFFICE.—Glenwood Springs. Hotels: The Colorado and numerous smaller hotels.

ACCESS—Viâ the Denver and Rio Grande and the Colorado Midland branch of the Atchison, Topeka and Santa Fé Railroad. (For climatic and topographical features of Glenwood Springs, *vide* vol. iii., p. 222.)

The following analysis of the waters at Glenwood Springs was made by Prof. Charles F. Chandler of New York.

YAMPA SPRING—MURIATED, SALINE, SULPHURETED.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	1,089.83
Magnesium chloride	13.09
Sodium bromide	.56
Sodium iodide	Trace.
Calcium fluoride	Trace.
Potassium sulphate	24.04
Calcium sulphate	92.38
Lithium bicarbonate	.22
Magnesium bicarbonate	13.55
Calcium bicarbonate	24.37
Iron bicarbonate	Trace.
Sodium phosphate	Trace.
Sodium biborate	Trace.
Aluminum	Trace.
Silica	1.97
Organic matter	Trace.
Total	1,260.01

Carbonic acid gas is copiously discharged from the springs. Sulphureted hydrogen is discharged in perceptible quantity.

The temperature of the Yampa, the largest spring of the group, as taken by the writer late in October, was 124.6° F., and of the "Chicken-broth" or "Cocktail" spring, 126.4° F. The specific gravity of the former when cooled down to 83° F. was 1.013, and of the latter a trifle less. . . . That the waters here are strongly impregnated with sulphureted hydrogen is amply attested by the heavy deposit of sulphur crystals on stones seen in the springs, and on the surrounding sandstone walls. In the Yampa Spring the gas is in sufficient quantity to impart a decided bluish tinge to the water, rendering it slightly opalescent. The atmosphere immediately surrounding the springs is heavily charged with the escaping vapor. . . . The waters of the springs in flowing into the great swimming-pool are cooled to some extent by contact with the air and by evaporation, but the temperature is further lowered by an artificial cold-water geyser near the western end of the basin, supplied from a nearby mountain reservoir. An average temperature of 93° to 98° F. is thus maintained, and bathing may be indulged in the year round. Another interesting and unique feature of Glenwood Springs should not pass unnoticed. Across the Grand River from the Hotel Colorado, and two or three hundred yards upstream, is the entrance to a cave which extends for a considerable distance under the mountain. This cave has a natural temperature ranging from 105° to 110° F., and the atmosphere is saturated at all times with the vapor of water strongly impregnated with sulphur like that at the springs. After one has remained for a few minutes in the cave the surface of the body becomes bedewed with a profuse perspiration. Advantage has been taken of this ready-made Russian-bath vapor chamber, and a bath-house with the requisite adjuncts has been constructed at its entrance. The cave itself is lighted by electricity, and attendants are on hand to supply the wants of bathers either in the caverns or in the private rooms.

As we have thus seen, the waters at Glenwood, besides being saline and sulphureted, are highly thermal. Fuller data concerning their exact remedial value are desirable. During the writer's sojourn at the springs a considerable number of persons, some of them from distant points, were using the baths, but they were for the most part acting under their own guidance and were not under medical observation. As far as could be learned, however, the evidence is strongly in favor of the utility of the baths in cases of chronic rheumatism, gout, cutaneous and renal diseases. . . . In common with all hot baths, these waters are contraindicated in fatty degeneration of any important structure, in atheroma, aneurism, or structural heart trouble, and in the predisposition to pulmonary, cerebral, gastric, or intestinal hemorrhage.

James K. Crook.

GLIOMA.—The glioma is a tumor consisting of proliferated neuroglia (the supporting tissue of the central nervous system) and of blood-vessels which are accompanied by a small amount of connective tissue. As the neuroglia cells are derived histogenetically from the epithelium lining the neural canal, the glioma is a tumor of which the essential or characteristic part is of ectodermic origin.

The glioma is found exclusively in the central nervous system of which it forms the commonest tumor. It occurs most frequently in the cerebrum, although the cerebellum is also a favorite site; it is found less commonly in the spinal cord. In the cerebrum it is often limited to the white matter and adjoining central ganglia, or it may arise from the latter and extend to the neighboring parts. Sometimes it reaches across the median line from one hemisphere to the other. It is more common in early than in adult life.

As a rule gliomata are solitary, but cases of multiple tumors have been reported Although the new growth generally appears well defined, the periphery is rarely sharply limited because a glioma is not surrounded by a capsule but tends to spread by infiltration of the adjoining brain tissue; it does not simply shove it back. By invasion of portions of convolutions it may enlarge them and render them denser or softer than normal. Gliomata do not, except possibly in rare cases (authorities differ), extend through the meninges or affect the bones of the skull, although they may set up a localized adhesive meningitis over the tumor. A zone of softening and of œdematous swelling often occurs for a greater or less extent around the growth.

In general a glioma of the brain is round. It varies ordinarily in size from a pea to a walnut, but in exceptional cases may be as large as an orange. In the spinal cord a tubular form is more common, probably on account of the pressure exerted by the narrow canal in which the cord lies.

The color of a glioma generally does not differ greatly from the white matter of the brain; it usually appears gray or yellowish-gray and rather translucent; but the more cellular forms may have a pinkish or reddish-gray or even dark red color from the numerous blood-vessels present. Degenerations, necrosis, and hemorrhages often cause marked changes in color, at least within the areas affected.

The consistence varies between hard and soft, depending chiefly on the number of cells and the amount of intercellular substance present in a given tumor, but œdema may also play an important part.

Two chief varieties of gliomata are recognized, depending on the consistence of the growth; these are the *hard* and the *soft* gliomata, but these descriptive terms really represent only the extremes of consistence, and all intermediate degrees occur. The term *myxoglioma* has in the past been applied to an œdematous glioma, but is manifestly incorrect because mucin has not been demonstrated to be present. A glioma containing numerous blood-vessels is sometimes called *glioma teleangiectodes.*

Secondary degenerations and necrosis are very common, as shown by yellow areas and by cysts of softening; the latter may occupy a large part of the original growth; they may contain a clear, cloudy, or dark brown fluid. In consequence of the numerous blood-vessels present, especially in the more rapidly growing gliomata, large and small hemorrhages are not infrequent; occasionally such a hemorrhage may be the cause of sudden death. As such vascular forms usually are soft, a large part of the tumor may be destroyed, so that careful and even microscopic examination may be required to determine the origin of the hemorrhage.

A glioma is essentially a benign growth; it does not give rise to metastases, but is dangerous partly on account of the pressure it exerts, partly from the destruction of the nervous tissue which it infiltrates.

Histologically the picture presented by gliomata varies greatly. In those of which the structure most resembles normal neuroglia the tumor tissue consists of round or oval vesicular nuclei surrounded by a slight amount of protoplasm and of chemically differentiated fibrillæ which are not processes of the cells but are an intercellular fibrillar substance. Several methods for staining them have been published. As in normal neuroglia tissue, these fibrillæ do not start from or end in the cells to which they owe their origin, but simply touch or adhere to the surface of the protoplasm in passing. They are generally straight or moderately curved, solid, smooth, and of uniform size, although the separate fibrillæ vary considerably in thickness; they do not branch or anastomose. This type of glioma (Fig. 2316) is particularly prone to infiltrate the surrounding nervous tissue. The peripheral limit of its growth is even more difficult to recognize under the microscope than in the fresh condition. Moreover, this type of glioma closely resembles the secondary growth of neuroglia tissue (*gliosis*) which takes place when nervous tissue is gradually destroyed, and also always forms to some extent around gliomata. It bears the same relation to gliosis that in the mesenchymal tissue a fibroma does to the fibrous or scar tissue formed in the liver and other organs under analogous conditions. There is this point to aid in the recognition of a gliosis: the form of the part affected is preserved in its normal relations, but shrunken in size.

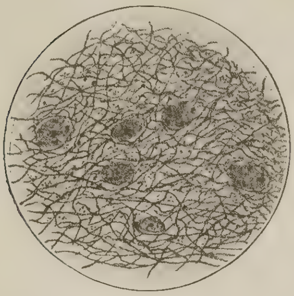

FIG. 2316.—From a Section of a Fairly Hard Glioma of the Small-Celled, Usually Infiltrating Type. The fibrillæ generally correspond in size to those of the normal neuroglia.

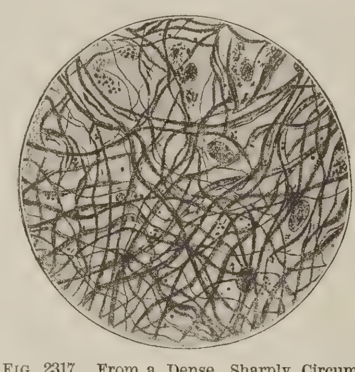

FIG. 2317. From a Dense, Sharply Circumscribed Glioma Containing Few Cells and many very Coarse Fibrillæ.

The density of this form of glioma depends chiefly on the relation between the cells and the fibrillæ; the more fibrillæ the greater the density. In one case studied the tumor (Fig. 2317) was very discrete in outline and dense to the touch; microscopically it contained few nuclei and great numbers of very coarse fibrillæ which could easily be distinguished from the fine fibrillæ of the gliosis surrounding the growth.

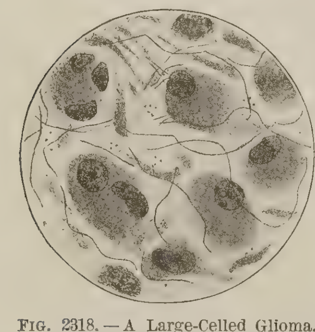

FIG. 2318.—A Large-Celled Glioma. The cells are often multinucleated, some have protoplasmic processes; the neuroglia fibrillæ are delicate.

In the cellular forms of gliomata (which correspond to the sarcomata of mesenchymal origin) the size of the cells in the different tumors varies greatly; large- and small-celled varieties are recognized. Whether differentiated fibrillæ are always produced by these rapidly growing gliomata is still an unsettled question. In a large-celled variety examined, in which mitotic figures were numerous, differentiated fibrillæ were fairly abundant in places (Fig. 2318).

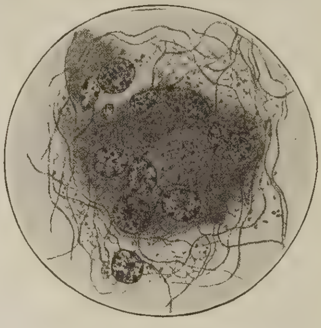

FIG. 2319.—From a Glioma Probably of Ependymal Origin. A clump of cells fused together and containing in their protoplasm differentially staining dots similar to those described by Weigert as occurring in the inner edge of ependymal cells and in the protoplasm of groups of epithelial cells lying near the neural canal.

To the above well-recognized types of gliomata another variety, never before described, must be added. It is as yet an unsettled question whether the ependymal cells lining the ventricles of the brain and the neural canal of the cord produce neuroglia fibrillæ; the relation of the ependymal cells to the neuroglia cells in post-embryonic life is therefore undecided. Weigert, however, has called attention to one peculiarity of ependymal cells: they each contain in the edge of the protoplasm lining the canal a small cluster of dots which stain by the differential methods for neuroglia fibres. In the cord just outside of the neural canal are often seen small clumps of epithelial cells in whose protoplasm similar differentiated dots appear. A very vascular tumor 4×5×3 cm., which hung from the roof of the fourth ventricle of the brain, was composed of cells arranged for the most part in clumps. The protoplasm of the cells was fused together; the nuclei, often six to a dozen or more in number, were arranged chiefly at the periphery. In the central part of nearly every one of these compound cells was a group of differentially staining dots lining a light staining circle in the protoplasm (Fig. 2319). Sometimes two or three clumps of dots were present. Similar groups of dots were found within single cells (Fig. 2320). There were also present in the tumor numerous small and large cysts (Fig. 2321) lined with epithelial cells in whose inner border occurred similar groups of dots. The so-called dots were not always round, but often appeared as short rods. Outside of the cells and cysts was a fine network of fine fibrillæ which stained differentially. This tumor would certainly suggest an origin from ependymal cells and the other cells mentioned above as occurring outside of the neural canal. It would also favor the view that at least some gliomata have their origin in congenital defects of development.

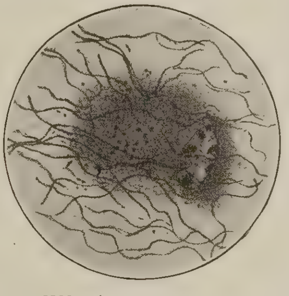

FIG. 2320.—(From same tumor as that shown in Fig. 2319.) A Single Cell Containing Similar Dots.

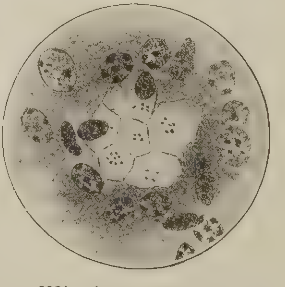

FIG. 2321.—(From same tumor as that shown in Fig. 2319.) The Bottom of a Small Cyst Showing the Dots in the Surface of Cells which do not Appear in the Section.

Gliomata of the retina have not been discussed because no one has yet shown by modern differential stains that they occur. The term *gliosarcoma* has been commonly applied to cellular gliomata; it can properly be applied only to a mixed tumor composed of rapidly proliferating neuroglia and mesenchymal tissues; it is extremely doubtful if such a tumor occurs. Another term that should be given up is *neuroglioma*. It should be applied to a new formation both of neuroglia tissue and of nerve cells. No evidence has yet been brought forward to prove that nerve cells in the central nervous system ever proliferate to form tumors. Nerve cells and nerve fibres often occur in gliomata in consequence of having been surrounded by the new growth. In certain large-celled gliomata some of the cells have protoplasmic processes and more or less resemble nerve cells, but they do not possess axis-cylinder processes or Nissl-granules; consequently they cannot be regarded as nerve cells.

The relation of glioma to syringomyelia will be discussed under the latter heading.

For the modern views on neuroglia tissue the reader is referred to Weigert's monograph, "Die Neuroglia," 1895. For a summing up of the neuroglia question to date, for the various differential stains for neuroglia fibres, and for complete bibliography see Huber, "Studies on the Neuroglia," *American Journal of Anatomy*, 1901, vol. i., p. 45. Consult also the article on *Neuroglia*.

F. B. Mallory.

GLOSSY SKIN. See *Hand and Fingers, etc.*

GLOTTIS, ŒDEMA OF. See *Laryngitis, Œdematous.*

GLOVES, USE OF, IN SURGERY.—Gloves have occasionally been used by surgeons at operations in order to protect the hand of the operator from foul discharges; but their general use to protect the patient from infective material introduced by the operator's fingers, has been developed in the last five years. The reason for this is the universally admitted fact that it is very difficult perfectly to sterilize the human hand. A secondary advantage of gloves lies in the saving of time and epidermis to the surgeon.

Various materials have been used to make surgical gloves. Wash-leather was one of the first, rubber cloth another; but as any thick glove is certain to make the fingers clumsy and blunt the sense of touch, such materials were found to be unsatisfactory. Gloves made of Lisle thread, and thin gloves of pure rubber have proved to be the most satisfactory, and these will alone be considered in detail.

Each material has its advantages. The cotton glove is cheaper than rubber, is more durable, is less easily torn, and is not slippery, a great advantage in some circumstances, as in tying ligatures, or in holding a slippery loop of intestine. Blood-smeared tools and fingers are slippery, and rubber increases this, while cotton does away with it.

On the other hand, the rubber gloves have certain advantages. Rubber is not porous, and hence no infective material can pass from the fingers to the wound through the glove if it is not pricked or torn. The tactile sense is better preserved through a thin rubber glove than through a thin cotton one. The very slipperiness of the rubber may be an advantage, as in thrusting the hand into the abdominal cavity. The chief point of difference, however, is the porosity of the cloth and the imporosity of the rubber. This makes the cotton more comfortable to wear, since the perspiration is not increased. The protection of the patient from infection is probably less perfect with the cotton gloves, especially if much fluid is used by the operator, or the operation requires much handling of wet tissues. In the ordinary dry operation, if the surgeon keeps his hands on the instruments and out of the wound as much as possible, the risk of infection must be a minimal one. If the cotton gloves become soiled they can be changed in a moment for others. In this way the risk of infection can be made still smaller.

Attempts have been made to render cotton gloves impervious to moisture by soaking them in various oils and other substances. The best results are obtained by use of a ten-per-cent. solution, in xylol, of paraffin of a low melting point. The gloves should be first dried in an oven, then immersed in pure xylol, and then for fifteen minutes in the paraffin solution. They are then taken out, dried, and sterilized by dry heat or steam. When soiled they may be washed with soap and water, dried, and again paraffined and sterilized. If cotton gloves are to be worn it is better to render the hands as nearly sterile as possible, before drawing them on, if the operation is such that the fingers must become wet.

Opinion is divided on the necessity of sterilization of the hands before operation, if rubber gloves are to be used. Theoretically this is not necessary, unless the glove is pricked or torn. In that case a new glove should be put on, or a thin rubber finger cot should be pulled on the affected finger. Some surgeons say that infection may take place in this way, and that therefore the hands should be disinfected before the operation. Even if this is done in a thorough manner, the gloves cause such an increase of perspiration, that the hands are certainly not sterile at the close of an operation, no matter what their condition may have been at its beginning. McBurney therefore advocates washing the hands simply with soap and water, drying them, and rubbing them with sterilized starch powder, to facilitate the putting on of the gloves. By avoiding the use of irritating antiseptic solutions, he says he is able to keep the skin of his hands in good condition, and thus to feel as well through the glove finger, as he could do without a glove if the skin of his fingers was harsh and rough.

The sterilization of rubber gloves is not so simple as that of the cotton ones, but it need by no means be so complicated as some of the directions imply. A simple and efficient method is as follows: Wash the gloves inside and outside with soap, hot water, and a little ammonia. Boil them for fifteen minutes in a one-per-cent. soda solution, taking care that they do not come into contact with any metal while in the sterilizer. Remove the gloves with sterile forceps and lay them in a sterile towel, which is then to be wrapped around them. It is not necessary to fill the glove fingers with gauze, nor to attempt to dry the inside of the gloves, as this necessitates some handling. If the hands are dry and are covered with sterile powder, the gloves can be drawn on without difficulty. This is a much better method than to fill the gloves with sterile water before putting them on. Water and perspiration will then continue to drip from the wrists at intervals during the operation, and the wound may in this way become contaminated.

A more complicated way in which to sterilize the gloves, but one by which they are kept perfectly dry, is the following: Wash the gloves on both sides with a one-per-cent. sodium-carbonate solution, rinse them in sterile water, and dry them over a flame. Dust them with sterile soapstone powder, wrap them in gauze or a towel, and sterilize them for two hours in a formalin oven.

There is no difficulty in having absolutely sterile clothing, water, sponges, towels, ligatures, sutures, instruments, and other utensils. The air and floor probably never cause infection. The skin of the patient must rarely do so, or stitch abscesses would be more common. The hands of the surgeon must therefore be held responsible for nearly all of the infection which arises in clean operative cases. In regard to the use of gloves McBurney naively remarks: "Those surgeons who already with naked hands have entirely satisfactory results certainly do not need rubber gloves. But I am sure that they will be useful to those who too frequently meet with imperfect results." The extent to which gloves have been taken up by the younger men as a routine surgical procedure in their operations, is a sufficient proof that their use will in a few years be recognized everywhere as a precaution which few careful surgeons will care to disregard.

Edward Milton Foote.

GLUCIN is the sodium salt of amido-triazin-sulfonic acid, and is obtained by the action of fatty aldehydes on the dye-stuff chrysoidin, with conversion of the condensation products into their mono- and di-sulfonic acids. Like saccharin, glucin is used as a sweetening agent in diabetes; but, while it is less sweet than saccharin, its taste is more like that of sugar. One part is equivalent to about one hundred parts of cane sugar. It is said not to interfere with the digestive functions.

W. A. Bastedo.

GLUTOID CAPSULES are gelatin capsules which have been hardened in formalin. They are made in three grades, capable of resisting the action of the gastric juice for from one and a half to twelve hours, and were introduced by Sahli for the conveyance of drugs which it is desired not to have set free in the stomach. As a stomach test, Fromme proposes the following: Potassium iodide is administered in these capsules, and if the iodide reaction in the saliva occurs within three and one-half to five hours there is good gastric motility and normal pancreatic digestion. The capsules are said to disintegrate readily in the pancreatic juice, but no statement is made as to the effect of the formaldehyde set free.

W. A. Bastedo.

GLUTOL, formacoll, formaldehyde-gelatin, or glycoform, is an odorless, coarse brownish-white powder, made by dissolving 500 gm. of gelatin or isinglass in water, adding twenty-five drops of formalin, and reducing to dryness in formaldehyde vapor. It is stable, indifferent, not liquefied or changed by heat or moisture, and can be sterilized. It is not of itself antiseptic, but, though tough and insoluble, it sets formaldehyde free and is absorbed when applied to raw animal tissues. It is said not to allow the formation of granulations, and to form a very hard clean scab. This, of course, must be watched lest it retain the secretions from the wound, or allow the collection of pus. In incised and lacerated wounds and abscesses, Foote (Vanderbilt Clinic, New York) has not succeeded in getting primary union, and the dressings were followed by pain lasting several hours, yet he considers it of much value. He uses it in the following manner: the skin is cleansed with soap and water, turpentine, ether and bichloride, cocaine is injected, a free incision is made, and pus and sloughing tissues are curetted away. The wound is then filled with glutol and a dry dressing applied. The glutol is soon absorbed so that the surfaces of the wound are not kept apart as by gauze packing. No drain is necessary, as the powder allows drainage by capillary action. It has not power to kill pus germs, but will control their development. Schleich, its introducer, Keen, Da Costa, and many other foreign and American surgeons have found it a valuable succedaneum for iodoform. Schleich sprinkles it over the surface line of sutures when operating.

W. A. Bastedo.

GLYCERIN.—Glycerin ($C_3H_8O_3$) is, chemically, an alcohol—propenylic alcohol ($C_3H_5(OH)_3$), and results from the decomposition of natural fats by alkalies. The United States Pharmacopœia recognizes under the title *Glycerinum*, Glycerin, "a liquid obtained by the decomposition of vegetable or animal fats or fixed oils, and containing not less than ninety-five per cent. of absolute glycerin." Glycerin can be obtained as a by-product in the making of lead plaster or of soap, but is derived in purest condition by acting on fats with water at a high temperature, under pressure. Under those conditions the fats break up into glycerin and fatty acids. Glycerin so prepared is known as *distilled glycerin*, and the famous Price's glycerin is of such kind. Glycerin appears as "a clear, colorless liquid, of a thick, syrupy consistence, oily to the touch, odorless, very sweet and slightly warm to the taste. When exposed to the air, it slowly abstracts moisture. Specific gravity: not less than 1.250 at 15° C. (59° F.). Soluble, in all proportions, in water or alcohol; also soluble in a mixture of 3 parts of alcohol and 1 part of ether, but insoluble in ether, chloroform, carbon disulphide, benzin, benzol, and fixed or volatile oils" (U. S. P.). On heating, glycerin undergoes some decomposition: boils at 329° F., and finally is wholly decomposed and dissipated.

In its medicinal relations glycerin is unique, because of the following combination of qualities: It is at once viscid, non-volatilizable, unalterable on exposure, antiseptic yet non-poisonous, and has an unusual range of solvent powers, dissolving bromine, iodine, sulphur iodide, the fixed alkalies, lime, tannic and other vegetable acids, many vegetable organic principles, such as salicin and santonin, sugar, gum, and pepsin, and very many inorganic salts. Physiologically glycerin, in concentrated condition, is somewhat irritant to very sensitive parts, probably because of abstraction of water from the tissues; but upon ordinary surfaces it is perfectly bland. Swallowed by the human subject in quantities of an ounce or more, glycerin produces no other effect than a very mildly laxative action; but experimentally administered to the lower animals it proves toxic, producing tetanus in the frog, apparently from direct action upon the muscular tissue (Amidon: *Archives of Medicine*, October, 1881), and varied signs of nervous derangement in rabbits and dogs, even to death by conjoint failure of respiration and heart action.

The uses of glycerin are, pharmaceutically, as a solvent, preservative, and sweet-tasting viscid addition to fluid preparations, or pill masses; and surgically, as an antiseptic, bland, and unalterable viscid application to wound surfaces and sores. Medically, glycerin has been used as a laxative in cases of hemorrhoids, as a preventive of flatulency, pyrosis, and the fermentation of the ingesta in the alimentary canal (Ringer and Murrell), and as a harmless sweetening addition to foods in cases of diabetes mellitus. A reputation which the substance once enjoyed, of tending directly to oppose the morbid process of diabetes, is now no longer credited. Glycerin may be given internally in quantities varying from a teaspoonful to a tablespoonful.

The United States Pharmacopœia makes official *Suppositoria Glycerini*, Suppositories of Glycerin. These suppositories are compounded of glycerin, with a little sodium carbonate and stearic acid, and each suppository contains 6 gm. (about gr. xciij.) of glycerin. They are used for the relief of constipation, but should not be employed habitually, for fear of irritating the bowel.

Certain solutions of substances in glycerin constitute pharmacopœial preparations called *Glycerites.*

Edward Curtis.

GLYCOSOLVOL is a diabetic remedy made by the action of oxypropionic acid on peptone, and by the action of sodium theobromine upon the zymogen of trypsin.

W. A. Bastedo.

GLYCYRRHIZIN. See *Licorice.*

GODBOLD MINERAL WELL.—Post-Office.—Summit, Pike County, Mississippi. Hotels and boarding-houses in Summit.

Access.—Viâ Illinois Central Railroad to Summit, thence a few minutes' walk to the well. This well-known chalybeate well is located in the suburbs of Summit, a village 108 miles northwest of New Orleans and 75 miles south of Jackson. The location is 420 feet above tide-water. The well has a depth of eighteen feet and a diameter of four feet. The supply of water is unlimited. The following analysis was made by J. H. Laster, chemist, of New Orleans:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Iron protochloride	11.42
Calcium sulphate	Trace.
Sodium chloride	1.73
Calcium carbonate	Trace.
Silica	"
Loss	.84
Total	13.99

The water is said to possess much value in the treatment of diarrhœa and dysentery and in disorders of the liver and kidneys. It is bottled and sold, but many persons visit the well in person for the purpose of drinking its waters. The water is almost a pure chalybeate, the remaining ingredients being practically inert.

James K. Crook.

GOERBERSDORF—This place is mentioned chiefly because it is the locality in which the renowned Brehmer Sanatorium – the oldest in existence, founded in 1854—is situated. The village of Goerbersdorf is located in the Southeastern part of Germany, in the province of Silesia, at an altitude of 1,840 feet. It is in the valley of the Steine, which runs from northwest to southeast, and is sheltered by densely wooded heights. The climate is not unlike that of the Adirondacks, for example, its main features consisting of "atmospheric purity, freedom from dust, dryness of soil, shelter against strong wind, and abundant sunshine." Its altitude is not sufficient to give it the character of an Alpine climate, though in a general sense it is a mountain climate. The season is an all-the-year-round one.

Here, nearly fifty years ago, Brehmer founded his famous sanatorium, the parent of all the others. Begun in a small way, it now consists of large and handsome buildings with several detached villas, surrounded by very extensive grounds. Meeting with much opposition at first, Brehmer, before he died in 1889, had the satisfaction of seeing his method adopted more or less closely in all systematic attempts to cure phthisis; other sanatoria established on the principles laid down by him; and more favorable results than had ever before been obtained in the treatment of the disease. To-day the Brehmer hygienic-dietetic treatment, with perhaps some modifications, is the best we have, when weighed by results.

Brehmer's theory of the underlying cause of phthisis was a disproportion between the heart and lungs, the latter relatively voluminous, the former small, with thin, flabby, feeble walls. Consequently he considered that the most important object in the treatment was to strengthen the heart, and methodic hill-climbing the best means for obtaining this result. For this purpose, in the park of about 300 acres surrounding the sanatorium, he constructed over nine miles of footpaths of gentle ascent, with frequent benches and pavilions for resting. Measured walks of measured steepness constituted at that time a fundamental principle of his treatment, and only the febrile cases and those with some contraindicating complication were exempt. The other sanatoria have modified this plan, and place the emphasis upon the *Ruheluft-Kur*, rest in the open air. This method is followed, to be sure, at Görbersdorf, but not to the extent that it is at Falkenstein and Hohenhonnef. At these latter it is the striking feature of the treatment.

The sanatorium building is a large gothic structure of brick, of very imposing appearance, in the midst of a beautiful garden; and besides the old and the new *Kurhaus* there are three annexes or villas. The internal arrangements are very extensive, consisting of a winter garden, conversation and reading rooms, large dining halls, various reception rooms, an imposing gothic staircase, and bedchambers hygienically arranged. One notices various suggestive maxims painted on the walls, like the following: "Wolle nur eins, und das wolle von Herzen" (Desire but one thing and that with all the heart). "Die lohnendste Arbeit für einen Kranke ist: gesund zu werden" (The labor which best repays a sick man is to get well).

Besides the sanatorium proper, there are two detached buildings of plainer construction, where patients are received at a reduced price. There is also a chemical and bacteriological laboratory, a meteorological observatory, and a medical library. The clientage comes from Germany, Russia, Hungary, Poland; and I found two patients from America. The supervision of the patient's life is most exact and continuous; every two weeks he is examined anew by the physician in charge, and is always under the observation of one or another of the physicians, all of whom, except the director, take their meals with the patients. Each is individualized in his treatment. As an illustration of the painstaking care, I noticed in the little reading library certain starred books, and on

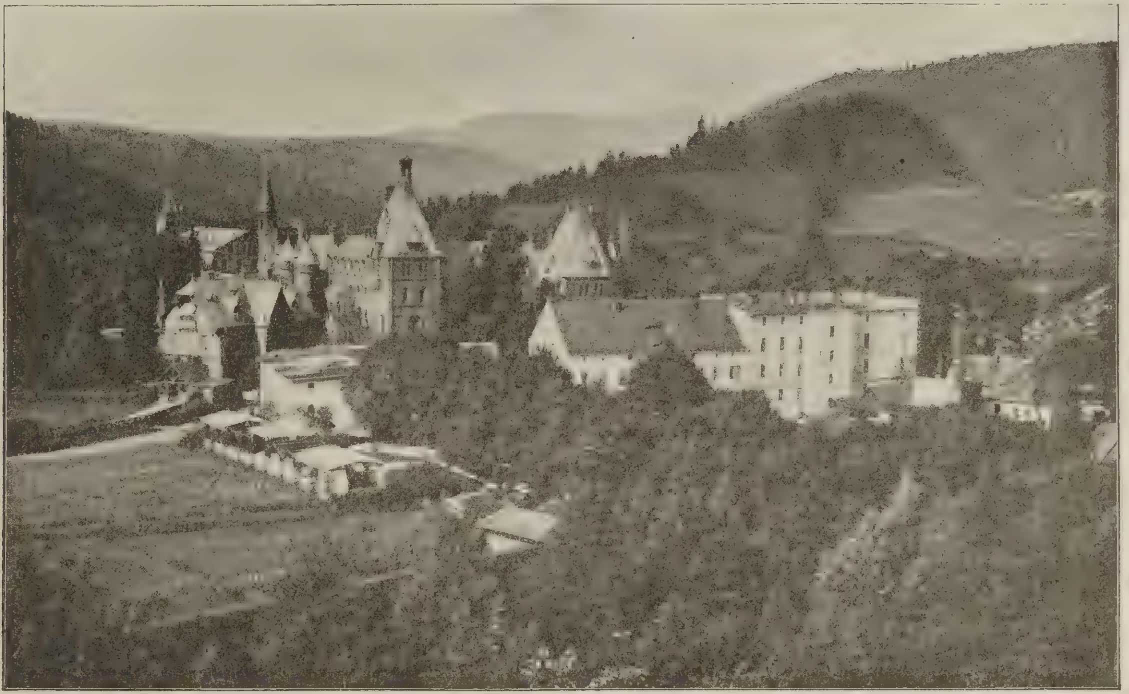

FIG. 2322.—Brehmer's Sanatorium at Goerbersdorf.

inquiry I found that they were of a rather exciting nature and were forbidden to those of nervous temperament as likely to produce a rise of temperature or some other unfavorable symptom. There are five meals a day, reinforced by milk. Kefir is prepared on the premises in large quantities and is much used, especially in gastro-intestinal troubles and in conjunction with alcoholic drinks for night sweats. Most of the patients use wine or beer. In fever milk is the principal diet, and as much as three litres in twenty-four hours is given a patient.

Hydrotherapeutics, as in the other sanatoria, is an important adjunct of the treatment in the form of simple bathing with acidulated water, the wet pack with massage, and cold douches. I was interested in watching the method of giving the latter. In a room adjoining the douche sits a physician at a table, with a watch provided with a second hand, and with the names of those for whom the bath is prescribed. The attendant informs the physician through a speaking tube when the patient is ready, and the doctor turns on the water (which he alone manipulates) for the specified number of seconds, as indicated in his list. When the douching is completed, the attendant throws a blanket about the patient and rubs him down. Only the stronger and convalescent patients are allowed this douche.

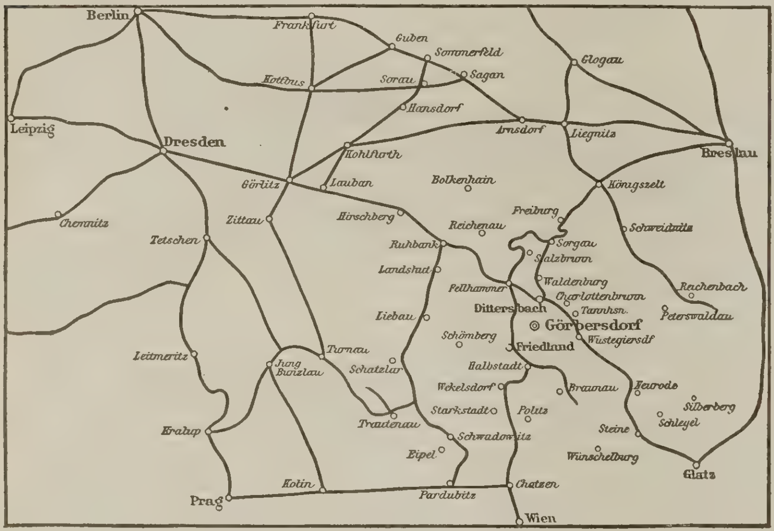

FIG. 2323.—Map Showing the Railroad Connections Between Goerbersdorf and some of the Chief Cities of Central Europe.

The sputum is deposited in shallow cuspidors containing sawdust, scattered about the building. Each patient also has a Dettweiler pocket spit-cup. The sputum is destroyed by burning.

A few minutes' walk from the Brehmer establishment brings one to Dr. Römpler's sanatorium, which is also extensive, accommodating about one hundred patients. Although not so imposing as Brehmer's, it is equally comfortable and complete, and, on account of the lighter character of the architecture, gives one a very pleasing and cheerful impression. In common with the other sanatoria, it possesses a fine winter garden, which is practically a great conservatory affording an extensive and beautiful view even to the horizon, and is the favorite lounging place for the inmates when the weather forbids outdoor life. The "Liegehalle" is in the second-story balcony with a glass roof, which seemed to me preferable to those on the ground floor. The extensive park is laid out with pleasant paths of varying grades (some protected) extending up to the richly wooded mountainside, with seats, terraces, and pavilions, which afford comfortable and picturesque resting places. The method of treatment is similar to that of the larger establishment; it comprises abundant alimentation, outdoor air (rest in the reclining chairs and walking in the paths of gentle ascent) and hydrotherapeutics.

Dr. Römpler's personality is most pleasing, which doubtless has much to do with the success he attains. He is a great lover of nature and inspires his patients with his enthusiasm for outdoor life. In a few words he well sums up the conditions of cure: "Upon the ability of the organism to *resist* depends finally the possibility of cure. To increase this power of resistance through gradual blunting of the susceptibility to irritation (hardening); through the improvement of the nutrition and quality of the blood; and, finally, through the avoidance of hurtful influences and through instruction and training for future guidance, is the principal problem of the phthisiotherapeutist."

The third sanatorium at Goerbersdorf is that of Dr. Weicker, which is a small one, and, as Dr. Weicker says, on the plan of a home rather than on that of a large institution, he and his wife living in the institution with his patients; and the method is essentially that of the others. It was originally founded by the Gräfin Pückler, under whose name it still stands. Dr. Weicker also has charge of a people's large sanatorium in Goerbersdorf, consisting of seven villas, which received 256 persons during the year 1896. It was established for working people who are members of the so-called insurance society for the disabled and aged; the expense being defrayed by the society, which allows each member a certain sum. The insurance societies of Germany of this nature are finding it to their interest to send their consumptive members to such an institution and have a certain proportion of them returned to their usual avocation, rather than support them indefinitely as invalids. Of 185 persons who were dismissed in 1896, 70.3 per cent. were capable of resuming their work; and for the three years from 1894 to 1896 inclusive, of those communicated with who were dismissed in these respective years as capable of resuming their work, 60, 71, and 89 per cent. respectively, still remained so at the beginning of 1897; so that from an economic point of view this plan of people's sanatoria is a profitable venture for the insurance societies.

Goerbersdorf is reached either viâ Breslau and Friedland, or from the station of Dittersbach on the Silesian Mountain railway. Either from Friedland or Dittersbach one has to ride four or five miles to the sanatoria. As to the results obtained at Brehmer's sanatorium, of 75,032 patients treated from 1876 to 1886, 26.6 per cent. were reported "cured and almost cured," of the first, second, and third stages of the disease collectively.

Edward O. Otis.

GOITRE.—(Synonyms: *Bronchocele, Struma, Derbyshire Neck, Kropf* [Ger.].) German writers apply the term "struma" solely to enlargements of the thyroid gland. Among English writers the word has a double meaning. It is used to indicate not only disease of the thyroid gland but also a tuberculous condition of the lymph nodes. Hence its use may lead to confusion.

The word "goitre" is probably a corruption of the Latin "guttur," the throat. Like many terms of popular origin it cannot be defined satisfactorily in scientific language. It is used rather loosely. It seems best to apply the term goitre to all enlargements of the thyroid gland. Wölfler, Orth, Kaufmann, and Ziegler use the word in this sense. Virchow, Murray, and Ewald attempt to restrict it to the benign thyroid tumors. If the use of the word is to be limited at all it would be better to designate as goitre that form only of thyroid tumor which occurs endemically or epidemically in certain regions of the world.

Historical Note.—The occurrence of endemic goitre is known to antedate the Christian era. That the disease abounded among the Alps was well recognized by the ancients. Juvenal asks—"*Quis tumidum guttur miratur in Alpibus?*" References to goitre by Greek and Roman physicians are few and indefinite. Paracelsus, who studied endemic goitre in the Duchy of Salzburg, was the first medical writer to treat of the subject in a satisfactory manner. In his work, which was based on personal observations, he indicated the relation of goitre to cretinism. Scientific inquiry in regard to goitre, according to Hirsch, may be said to date from the work of Malacarne, published toward the close of the eighteenth century.

Knowledge of the pathological anatomy of thyroid tumors began with the studies of Ecker, Frerichs, and Rokitansky. A little later Förster's monograph on the malignant tumors of the thyroid appeared. In 1867 Virchow published his classical description of the anatomical forms of goitre. Wölfler in 1883 finished his monumental work on the development and structure of thyroid tumors. Clinical knowledge of the subject has been greatly advanced by the work and writings of Lücke, Kocher, Ewald, Berry, and Murray.

In America, the first and only attempt at a systematic study of the distribution of goitre was made by Benjamin Barton, professor in the Medical School of the University of Pennsylvania, and was issued in 1800. The monograph was entitled "A Memoir Concerning the Disease of Goitre as it Prevails in Different Parts of North America." W. Gibson in 1820 published an able essay which included a study of the morbid anatomy and means of diagnosis of thyroid tumors.

In Dr. Osler's paper on cretinism published in 1893 he showed that endemic goitre no longer exists in those regions where, early in the last century, it prevailed extensively. The endemic disease has been studied in Michigan by Dock, and among the North American Indians by Munson.

Anatomy.—The thyroid (*glandula thyreoidea*) is a ductless gland, which consists of two lateral lobes connected by a middle portion, varying markedly in size, called the isthmus. The thyroid gland lies in front of the larynx and trachea, and is bound to them by fibrous bands so that it follows the movements of these organs in deglutition. The outer margins of the lateral lobes are anterior to the common carotid arteries. Sometimes a slender pyramidal process (*lobus pyramidalis*) projects upward from the middle of the isthmus to the hyoid bone. The lateral lobes (*lobus dexter et sinister*) measure 5 to 7 cm. in length, 3 to 4 cm. in breadth, and 1.5-2.5 cm. in thickness. The weight of the entire gland varies between 30 and 60 gm. (Orth). Weibgen found that the most active growth occurs between the eleventh and twentieth years. The average weight between the sixth and tenth years was 11.9 gm., between the eleventh and twentieth years 36.7 gm. The thyroid is slightly heavier in men than in women. It is relatively larger in the young than in adults.

Although a portion of the lateral lobes is developed from the fourth branchial clefts, the greater part of the gland arises as a diverticulum of the pharynx.

In the embryo the thyroid body consists of solid nests and strands of epithelial cells. Later these solid masses become converted into closed vesicles filled with colloid and lined with a single layer of cylindrical or cuboidal cells.

Wölfler holds that small nodules of embryonic tissue are normally present in the developed gland, and furnish the congenital *Anlage*, in the sense in which Cohnheim used that term, for the development of tumors. It is fully as probable, however, that these embryonic remains which Wölfler describes are in reality small adenomas.

His has described what he considers to be the rudiments of an excretory duct (*ductus thyreoglossus*) which extends from the thyroid to the tongue and opens at the site of the foramen cæcum. The finding of accessory thyroid tumors in the root of the tongue is certainly in support of this view, although Kanthack was not able to confirm the observations of His.

The thyroid vesicles range from 0.045 mm. to 1 mm. in diameter. The epithelial cells vary in size and shape. Sometimes in young individuals they have a cylindrical form, but usually they are cuboidal. Low, flat cells, according to E. Schmid, are seen chiefly in old age. On fresh examination colloid droplets and a varying number of fine and coarse granules can be demonstrated within the cells. The granules are most abundant near the free margin of the cell.

The viscid, homogeneous colloid substance present in the vesicles usually appears vacuolated in hardened specimens (see Fig. 2324). It takes nearly the same color with eosin as do the red blood corpuscles. Ernst has shown that colloid can be distinguished from hyalin by staining more deeply with fuchsin when treated with Van Gieson's mixture.

The origin of colloid has not been fully determined. It is probably a secretion of the epithelial cells. These have the characteristics of secreting cells. Virchow believes that the cells secrete a clear fluid into the vesicles, and that the colloid is formed from the fluid. Many histologists and physiologists hold to the view of Frerichs that colloid is formed within the cells or is the product of a specific transformation of the cells. They regard the process as partly secretory and partly degenerative. Reinbach holds that colloid in normal glands is a secretion, but the colloid in goitres is formed by the degeneration of the cells. He adduces little evidence in support of the latter hypothesis, and Müller is probably right in regarding the colloid substance of both normal and goitrous thyroids as a secretion and not a degeneration.

How the thyroid secretion enters the circulation is not known. The explanation of Biondi and Schmid that rupture of the vesicles occurs as a physiological event and thereby the colloid escapes into the lymphatics is improbable. The existence, between the epithelial cells, of ducts communicating with the lymphatics, as described by Hürthle, is doubtful.

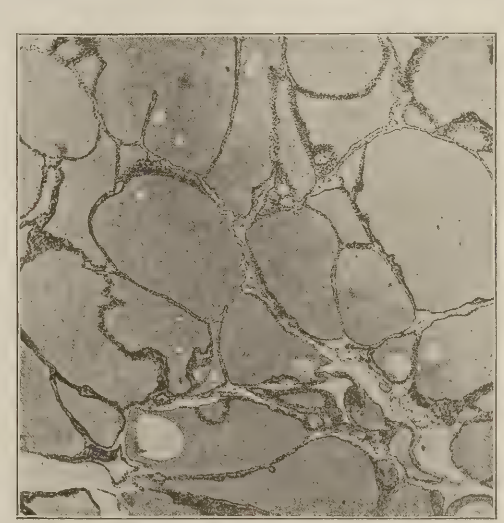

Fig. 2324.—Accessory Thyroid Tumor from Root of Tongue. The vesicles are filled with colloid and lined with low epithelium. (× 41 diam.)

A number of histologists have described colloid within the lymphatics of the thyroid, and Podack found it in lymphatics outside of the thyroid. The observation by

Zielinska of colloid in the capillaries, veins, and even in the arteries of the thyroid and by von Ebner in the vessels of the larynx, would seem to show that this supposed demonstration of colloid within vessels is due to an artefact possibly produced in removing the organ or in the process of hardening. It may be coagulated blood serum which sometimes simulates colloid in appearance. I have recently studied a specimen of syphilis of the testicle in which the veins were filled with a homogeneous hyaline material which presented exactly the appearance of the colloid of the thyroid. Fine projections of the hyaline material attached it to the walls of the vessels which gave the festooned border seen in thyroid vesicles. This observation suggests that the lack of apposition between the epithelium of the thyroid vesicles and the colloid mass is not due to the presence of a clear secretion between the epithelium and the colloid mass, but to a retraction of the latter.

The morphology of the epithelial cells and their relation to the abundant capillary network rather favor the view that the thyroid secretion passes without the intervention of lymphatics directly into the circulating blood.

The thyroid is an extremely vascular organ. Mayer estimated that it receives almost as much blood as the forearm. Sömmering calculated that the size of the thyroid arteries was relatively eight times greater than those of the brain. Both the arteries and the veins form large anastomoses upon the surface of the organ.

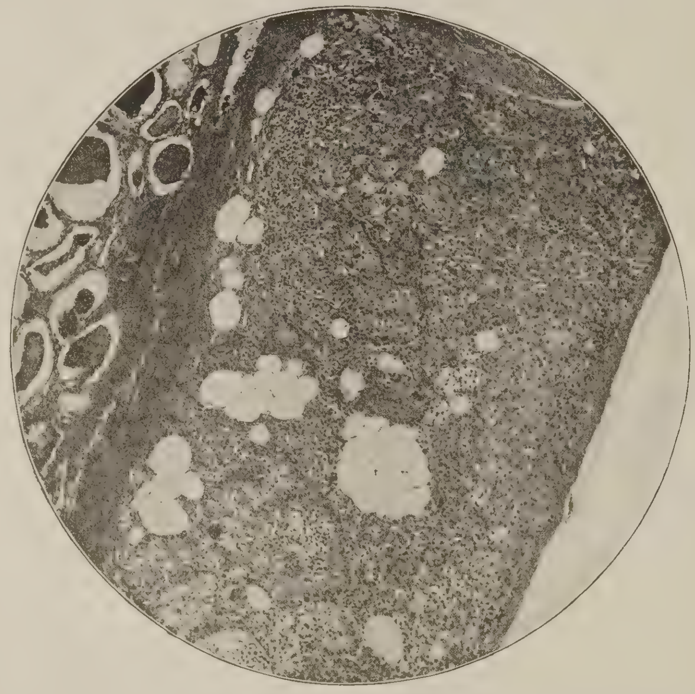

FIG. 2325.—Section Through a Parathyroid of Man. It is contiguous to the thyroid gland. The difference in structure between thyroid and parathyroid tissue is well shown. (× 85 diam.)

Horne in 1892, working under von Recklinghausen, described bud-like projections composed of proliferated endothelial cells on the inner wall of the arteries of goitrous thyroids. M. B. Schmidt found similar cell buds quite regularly in the small arteries of the healthy thyroid at all ages. They may involve the media as well as the intima. The significance of these nodules is not known. Ricker has suggested that they represent a temporary infolding of the wall and thus offer a morphological explanation for the great variations in the blood content of the gland. Years ago the idea was advanced that the thyroid was, in a certain sense, a safety reservoir to prevent an excessive flow of blood to the brain.

Accessory thyroids (*glandulæ thyreoidæ accessoriæ*) are not rare. They may occur anywhere from the root of the tongue to the middle of the thorax, but they are most frequently found in the neighborhood of the hyoid bone. Zuckerkandl found them anterior to the hyoid bone in fifty-seven out of two hundred cases.

Streckeisen distinguishes between the median and the lateral accessory thyroids. The former he divides into four groups: (1) the *prehyoid* which lie superior to the mylohyoid muscle; (2) the *suprahyoid* which lie between or within the geniohyoid; (3) the *epihyoid* which lie above the geniohyoid; (4) the *intrahyoid* which lie in the hollow or even in the substance of the hyoid bone. The lateral accessory thyroids are usually found in the neighborhood of the greater cornua of the hyoid.

Wölfler has observed accessory thyroids on the ascending aorta in children. In dogs they are commonly found in this situation. Piana states that aortic accessory thyroids were present in sixty-six per cent. of the dogs examined. In cats accessory thyroids are rare.

PARATHYROID GLANDS (*Glandulæ parathyreoideæ*).—These bodies were described first by Sandstroem in 1880. They are composed of solid masses of epithelial cells, and do not contain colloid. The parathyroids in man have been studied by Welsh, of Edinburgh. As a rule, there are two parathyroids on each side. Sometimes the distribution is irregular, so that one or more may be overlooked. Two glands may be intimately connected so that they appear, on superficial examination, as one gland. They vary in size, but most commonly measure about 6×3 ×1.5 mm. I have seen them 1 cm. in length, and Welsh states that they may measure 1.5 cm. They are thin, oval bodies which are moulded to the form of adjacent structures. Their characteristic color is yellow, admixed with red and brown. The yellow hue is due to clusters of fat cells lying between the masses of epithelial cells. This adipose tissue within the gland is well shown in Fig. 2325. The two parathyroids, according to Welsh, have a constant position in relation to each other. Welsh designates them as the *posterior superior* and the *anterior inferior*. The posterior superior parathyroid lies on the posterior wall of the pharynx or œsophagus at the level of the inferior border of the cricoid cartilage, just internal to the posterior margin of the lateral thyroid lobe. The position of the anterior inferior parathyroid is less constant. The parathyroids differ from the thyroids developmentally. They are formed earlier.

PHYSIOLOGY.—The thyroid secretes a material which is essential to the well-being of the body. Notkin's view that the thyroid serves to collect some toxic substance from the blood is interesting but improbable. The internal secretion into the blood appears to be specially concerned in producing metabolic changes in the central nervous system. In 1856 Schiff showed that complete extirpation of the thyroid in dogs resulted in the death of the animal. Some, however, recover, and in 1899 Katzenstein concluded as a result of his experiments that the thyroid is not essential to life. He probably overlooked the accessory thyroids that are so common, as Sultan (*Archiv für klinische Chirurgie*, 1901, vol. lxii., p. 620) found that total extirpation of the thyroid tissue always produces severe, characteristic, disease phenomena, and leads to a fatal issue.

If, in the dog, one lobe be removed, although no symptoms supervene, the other undergoes a compensatory hypertrophy. This was pointed out by Wagner. The remaining lobe does not always enlarge, so, as Halsted says, the microscope must be the criterion of hypertrophy. The microscopical changes have been described by Horsley and Halsted. The vesicles enlarge. Their lining membrane becomes folded and branched. The epithelium assumes a cylindrical form, and the colloid disappears. Beresowsky removed five-sixths of the thyroid in dogs. In addition to compensatory hypertrophy he observed actual regeneration with new formation of vesicles.

Edmunds found that if one parathyroid be left in the animal the other parathyroids and the entire thyroid might be removed, and yet the dog would live and no apparent ill effects follow. The parathyroid that is left shows signs of active growth, but it does not develop into thyroid tissue. This overthrows the old view of Gley that the parathyroids are immature thyroids. Edmunds observed that compensatory hypertrophy of the thyroid took place when the thyroid was left intact, if all the parathyroids were removed. Excision of a portion of the superior laryngeal and vasosympathetic nerves on one side and of the lateral thyroid lobe on the other side leads to great hypertrophy of the remaining lobe. It may weigh three or four times as much as normal. The increase in size is largely due to a growth of thyroid tissue between the vesicles (Edmunds).

The experiments of Vassale and of Moussu show that the thyroid and the parathyroid are different organs. It is probable, however, that they are functionally associated. The removal of the former produces trophic disturbances resembling those of myxœdema in man, and removal of the latter produces convulsive disorders and death.

Levin's work seems to indicate that the thyroid secretion acts upon mucin. He demonstrated that an intravenous injection of mucin which is fatal to animals deprived of their thyroids gives rise to no untoward effect in healthy animals.

The colloid substance of the thyroid gland has great physiological power. It contains phosphorus, and yet is not a nucleoproteid, neither is it allied to mucin. It belongs to the glycoproteids. The singular feature about colloid is that it contains iodine. This notable discovery was made by Baumann who isolated a substance to which he gave the name iodothyrin, and which Hutchinson showed is found in the colloid substance. It contains all of the phosphorus and the greater part of the iodine. Oswald, in 1899, obtained from the complex iodothyrin the simpler body thyreoglobulin, which de Cyon and Oswald (*Pflüger's Archiv*, 1901, vol. lxxxviii., p. 199) claim is the active principle of the thyroid secretion. Baumann estimates that every gram of the thyroid of man contains 1 mgm. of iodine. Gideon Wells has shown that the human thyroids obtained in Chicago contain four times as much iodine as the glands of individuals living in the goitrous regions of Germany. The thyroid of newly-born children is free from iodine. The accessory thyroids may be richer in iodine than the thyroid gland proper (Gley, Mendel).

GEOGRAPHICAL DISTRIBUTION OF ENDEMIC GOITRE.—In certain districts, widely scattered over the globe, a goodly proportion of the inhabitants are affected with enlargement of the thyroid. This peculiar form of thyroid tumor is known as endemic goitre.

Early in the last century the disease prevailed in New England and in New York State. Dorr, writing in 1806, mentioned a number of New England towns in which goitre was very common. In 1893 Osler reported that the disease no longer existed in these towns. In many towns of Vermont it was especially prevalent. Dorr states that in Chester one-half of the inhabitants were affected. Osler found that goitre is now rare in Alabama, although it was common in 1854, and it is also interesting to note that the disease has gradually disappeared from those parts of Virginia where it was formerly endemic. Barton states that in 1798 bronchocele prevailed to such an extent in Pittsburg that out of fifteen hundred inhabitants no less than one hundred and fifty had the disease. The number of cases gradually declined, and in 1825 Denny wrote that no new cases had occurred since 1806.

As both Hirsch and Osler complain that they have been able to learn nothing of the occurrence of endemic goitre in Massachusetts, I have made inquiries of physicians in various parts of the State, especially of those connected with the hospitals for the insane. I have not been able to discover a single focus of the disease in the State.

Dock has found that goitre prevails in all parts of Michigan, but particularly in the northern section. The southern portion of the lower peninsula also contains many cases. Dock asserts that the disease exists in parts of Ohio and Indiana, and still more in the States bordering on Lakes Michigan, Superior, and Huron.

In 1895 Munson published his observations on the occurrence of endemic goitre among the Indians of the United States. A century before Barton called attention to the frequency of the disease among the Indians of New York State. Munson found goitre most prevalent in the southern part of Montana. It is common on the single reservation in Wyoming, and on the reservations of Utah, Idaho, and Colorado, situated on the western slope of the Rocky Mountains. It abounds in the western portion of the Dakotas, especially in the region of the Black Hills. The district examined includes a total of 18,182 Indians, made up of various tribes, and from this number were reported 764 cases of goitre, which is over four per cent. Munson states that the disease is frequently seen among the Chippewas of Minnesota, and is especially prevalent among the Menominees of eastern Wisconsin. "With the exception of a single reservation in Southern California, goitre is unknown throughout Washington, Oregon, western Utah and Idaho, California, Arizona, and New Mexico, although this region contains a comparatively dense Indian population."

In the Province of Quebec (Osler) and the Island of Montreal (Adami) endemic goitre occurs. It is still more common near Lake Ontario in the Province of Ontario. Osler mentions the extraordinary prevalence of this affection in the Kingston Insane Asylum, where in 1893 there were 288 cases of goitre among 600 patients.

In England endemic goitre is especially common among the Derbyshire Hills, hence the name Derbyshire Neck. It exists in the Pennine range in the North. Morris in 1895 stated that he had seen fifty cases among a population of two thousand in the Chiltern Hills. The greatest centres in Scotland are in the Lowlands and in and around the Lothian Hills (M'Kenzie).

A glance at the map prepared by Bircher shows in a striking manner the association of the disease with the mountainous countries of Europe. In Switzerland it is very prevalent. Bircher found that in some parts of the cantons of Freiburg and Berne eighty or ninety per cent. of the recruits were goitrous. In Italy the disease is common on the southern side of the Alps. It also exists in Savoy, in the Black Forest, and in Styria. The departments of France chiefly affected are those occupying the regions of the Alps, the Pyrenees, the Central Plateau, the Jura, and the Vosges. The disease has diminished in France, especially during the last fifty years, yet it is estimated that there are now between 375,000 and 400,000 goitrous people in that country (Mayet). The distribution of the disease throughout Europe is much the same as it was several centuries ago.

In Asia endemic goitre exists in the Himalayas, in the hilly districts of China, and in Siberia.

A great zone of goitre begins in Mexico and extends with increasing intensity through Central America and South America as far as Chili, and "forms a region of the disease worthy to be named besides those of the Alps and the Himalayas" (Hirsch).

ETIOLOGY OF ENDEMIC GOITRE.—Goitre is said to occur in endemic, epidemic, and sporadic forms. The term "sporadic" in this connection is unfortunate and misleading. It implies that the cause of the scattered cases of thyroid enlargement which are found everywhere is the same as that of endemic goitre. Like other glandular organs the thyroid may be the seat of a variety of new growths. The etiology of these tumors will probably remain obscure until more light has been thrown on the formation of tumors in general. In Massachusetts endemic goitre does not exist, and yet I have been able to collect in Boston over fifty specimens of thyroid tumors which have been removed during the past few years. These would be classified as "sporadic" cases, and yet the evidence is all opposed to the view that they were caused by the same agent that produces the endemic disease.

The cause of endemic goitre is not known. There seems to be little doubt that it is an infectious disease; but the *contagium vivum* has not been discovered.

Epidemic outbreaks of goitre may occur. With rare exceptions they have developed in districts where endemic goitre existed. Nearly all the cases have been observed in France. The epidemics have always been sharply localized. Most of them have been in barracks or boarding-schools. At Clermont-Ferrand fifty of the seminary pupils were attacked within a few days.

St. Lager in 1868 stated that he could number no less than 378 authors and 42 different views of the causation of the disease.

The geological formation has been held by some recent writers to be of importance in the genesis of the malady. Bircher concluded, as a result of careful study, that it occurred only upon the marine deposits, especially of the Palæozoic, Triassic, and Tertiary periods. He held that volcanic rocks, the crystalline rocks of the Archæan group, chalky sediments, and those of the Jurassic formation, as well as all fresh-water deposits, were free from goitre. Kocher in 1889 pointed out that it existed on the rocks exempted by Bircher, and Dock has shown that in America goitre is found on the Laurentian, the drift, and many intermediate formations.

For a detailed account of the various theories and the evidence adduced in support of them Hirsch's "Handbook of Geographical and Historical Pathology" should be consulted. His conclusion is so reasonable and so well stated that I give it in full: "The absence of results to all these inquiries about the genesis of goitre and cretinism—inquiries which have extended to every influence perceptible to the senses that could be brought into the consideration of the question before us—warrants, I will not say compels, the conclusion that in these diseases we have to do with a specific agent, *a veritable morbid poison*, and that endemic goitre and cretinism *have to be reckoned among the infectious diseases.* This doctrine finds a certain support in two things: on the one hand the fluctuations in the amount of the sickness, which we have had frequently occasion to notice, and for which there is no sufficient explanation to be found in the states of the atmosphere or of the soil or of hygiene; on the other hand, the epidemic outbreaks of goitre, for which the theory of infection, as Saillard, Viry and Richard, Thibaud, and other French military surgeons have recognized and said, is hitherto the only one that affords an explanation, and an explanation that accords most nearly with the facts of the case."

The infectious agent is probably conveyed through the drinking-water. The water of certain wells is known to cause goitre, and there are some in Switzerland whose water Kocher found had invariably produced goitre in the children who drank of it. The water is rendered harmless by boiling. There are noted goitre wells in Europe to which young men wishing to avoid enlistment resort. In a few weeks goitres develop which are large enough to exempt them from military service.

Dock noted that a very large proportion of all the cases in Michigan had used well-water. In Ludington goitre became much less frequent when lake-water was substituted for well-water. Singularly enough, according to a statement made by Dr. Hurd, the reverse is true at the Kingston Insane Asylum, Ontario. There, the patients developed goitre when the water of the River St. Lawrence was substituted for well-water.

Numerous attempts have been made to show a causal relation between certain micro-organisms and goitre. Klebs detected some minute animal or vegetable structures, which he called "naviculæ" from their shape, in the water of goitrous wells. Rüdel was not able to find these peculiar organisms. Bircher found diatoms and other micro-organisms in water from districts where goitre is prevalent.

Kocher discovered that water from goitrous wells is characterized by the large number of bacteria it contains. Tavel compared goitre-water with that of wells known to be harmless. Both were pure upon chemical analysis, but the former contained more bacteria. One bacillus isolated from two goitrous waters produced hypertrophy of the thyroid when inoculated into guinea-pigs. Experiments with this bacterium upon dogs yielded negative results. Lustig and Carle claim that a bacillus with definite characteristics is constantly present in water known to induce goitre.

Grasset in 1898 described a hæmatozoon, somewhat similar to the parasite of malaria, in the blood of goitrous individuals. M'Kenzie has not been able to confirm Grasset's observations.

Adami thinks that if micro-organisms cause the malady they do so indirectly, by forming injurious products in the water. The disease would then be regarded not as an infection but as an intoxication.

Endemic goitre is more common in women than in men. In England the proportion is from 7 to 1, to 44 to 1 (Murray). It usually develops at or before puberty. Hausleutner said that it rarely, if ever, occurred after the fortieth year; but we now know that cases may occur in older people.

In goitrous localities the lower animals are frequently affected, especially dogs and horses. Dock saw in a short time one day in Calumet, Michigan, six goitrous horses.

CONGESTION.—Vascular disturbances of the thyroid are favored by the richness of its blood supply. A transient enlargement occurs under a variety of conditions. There seems to be a definite connection between the sexual functions and the thyroid gland. Prof. Milnes Gaskell has shown that in the primitive vertebrate—the human progenitor—the sexual organs lay in intimate relation with the thyroid. Freund's careful investigations would seem to prove that a physiological enlargement occurs during menstruation and pregnancy. Transient swelling is also a consequence of parturition. Lange examined over three hundred pregnant women and confirmed Freund's observations. He does not agree with Freund, however, that the swelling is due simply to congestion. As reduction followed the administration of thyroid extract Lange maintains that the condition is due to a hypertrophy of the glandular elements.

It is also claimed that defloration is accompanied by an enlargement of the thyroid. If this be true there is a scientific basis for the ancient custom,* still followed in the East, of testing a bride's virginity by measuring the circumference of her neck before and after the marriage-night.

Sexual excitement in women and in animals is said to produce an engorgement of the thyroid. I have been told of a case in which a physician measured his wife's neck immediately after coitus and found a definite increase in the size of the thyroid. Berry says that one of his patients insisted that sexual excitement was always followed by temporary enlargement of his goitre, usually sufficient to cause dyspnœa.

In girls enlargement of the thyroid is common at puberty. Schönlein, Friedreich, and Heidenreich described it as a special type of goitre, the *struma antemenstrualis.* The swelling is probably due to hyperæmia or congestion. A connection seems to exist between thyroid enlargement and chlorosis. Ewald in Berlin, a nongoitrous locality, has been struck with the frequency of goitre in chlorotic girls. Capitan has called attention to this association. He thinks chlorosis is sometimes dependent upon abnormalities in the thyroid gland. Hayem in thirty-five subjects of chlorosis examined within a short time found goitre twenty-nine times.

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* "*Non illam genitrix orienti luce revisens hesterno poterit collum circumdare filo.*" Catullus, *Epigram 1.*

A case of acute enlargement of the thyroid in mumps has come under my notice. The patient was a student in the Harvard Medical School. A few days after the onset of the disease a swelling of the thyroid was observed, which continued to increase for several days. The gland was neither painful nor tender. There was slight dyspnœa. It remained enlarged for about two weeks. The case appears unique. There is no reference to this complication of mumps in the "Index Catalogue of the Surgeon-General's Library."

Alfred Stengel recently reported an interesting case of acute non-inflammatory thyroid enlargement. It was probably the result of congestion.

HYPERTROPHY.—When a portion of the thyroid is removed the remainder undergoes a compensatory hypertrophy. This type of hypertrophy is known to occur in man and it has been produced experimentally in animals by Ribbert, and Beresowsky. Berry relates a case in which symptoms of cachexia thyreopriva, which appeared after a supposed complete thyroidectomy, disappeared upon the development of a small tumor at the site of the operation. Either a bit of the goitre, fortunately not removed, or an accessory thyroid, had undergone compensatory hypertrophy and assumed the function of the normal thyroid.

It is possible that many of the thyroid enlargements in which the histological structure resembles that of the adult normal gland, and which I class as simple adenomas, are, in reality, examples of hypertrophy. Wölfler has attempted to separate the hypertrophies from the simple adenomas. The former (*Hypertrophia parenchymatosa et hypertrophia gelatinosa* Wölfler) are produced by an increase or enlargement of the normal vesicles or an increase in their contents, the latter (*adenoma gelatinosum*), he holds, are developed from embryonic remains. But as different writers (Birch-Hirschfeld, Orth, Weichselbaum, and Kaufmann) have stated, this distinction is not practical.

CONGENITAL GOITRE.—In goitrous districts congenital thyroid enlargement is frequent. Among 642 cases of goitre in children at Berne, Demme found 53 in which the disease was congenital. Usually the goitre is small, Virchow pointed out that it might readily be overlooked owing to its high situation in the neck. It frequently lies in close relation with the hyoid bone and may extend behind the pharynx and cause severe dyspnœa or even suffocation. Congenital goitre is not uncommonly associated with enlargement of the thymus (Virchow, Bednar).

The tumor may be very large. Hecker reported a case in which the goitre in a child who died at birth from asphyxia weighed 41.6 gm. Probably the largest congenital goitre on record is the one cited by Demme, which weighed 102 gm. In the museum of St. Bartholomew's Hospital is a huge congenital goitre. A photograph of the specimen appears in Mr. James Berry's recent work "Diseases of the Thyroid Gland."

Thyroid tumors have been found in embryos. Danyau described one in a fœtus of five and a half months. It formed a mass the size of a hen's egg and weighed 46 gm. The normal weight of a thyroid at this period never exceeds 1 gm.

Congenital goitre is rare in regions free from the endemic disease. Abt lately observed a case in Chicago. The child died at birth. The tumor was the size of a walnut and involved the entire gland.

Congenital goitres may have the structure of a normal fœtal thyroid and are then regarded as examples of hypertrophy (Spiegelberg, Fröbelius, Wölfler). Colloid cysts sometimes of large size have been observed. Congenital goitres are found in animals also (cattle, horses, goats, sheep, and dogs). For a comparative study the monograph of Pflug should be consulted.

Large goitres may offer a mechanical obstruction to the delivery of the child or they may cause face presentation.

BENIGN TUMORS—*Classification.*—Virchow's division of benign goitres into the following anatomical varieties is usually adopted: hyperplastic, fibrous, colloid, cystic, and vascular. This classification is based entirely on the macroscopic appearances. Wölfler attempts to classify them according to their mode of origin. His explanation of the mode of origin of the different types of thyroid tumors, however, is not convincing, and is largely hypothetical. The genesis of thyroid tumors will probably remain obscure until the general laws governing the formation of tumors are understood.

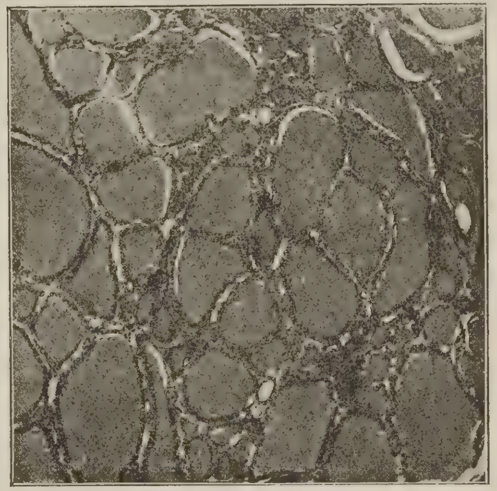

FIG. 2326.—Simple Adenoma of the Thyroid. (× 61 diam.)

As a classification is needed for the study and diagnosis of thyroid tumors, and as neither system at present in use is satisfactory—Virchow's, because it deals only with the naked-eye variations, and Wölfler's, because it is complicated and artificial—the attempt has been made to arrange these tumors into groups according to their histological structure. To this end I have read the objective descriptions of thyroid tumors given in the literature and have personally examined many specimens.*

There are three primary types of benign adenomatous thyroid tumors. All of these would be classed by Virchow as hyperplastic or parenchymatous goitres. They can be diagnosed with certainty only by microscopical examination.

1. Simple adenoma.
2. Fœtal adenoma.
3. Papilliferous adenoma.

The vast majority of all cases are of the first type. The third is the most rare.

Simple adenoma (Fig. 2326).—It is composed of vesicles of various size filled with colloid. The structure resembles closely that of the normal adult thyroid. The epithelium lining the vesicles may be low and flat (Fig. 2324) or it may be cuboidal (Fig. 2326). In the intervesicular tissue similar cells are sometimes seen arranged in solid masses or forming small rosettes. These are probably areas of undeveloped thyroid tissue.

The simple adenoma may be confined to one lobe, or it may appear as a diffuse growth involving the entire gland or form a distinctly encapsulated tumor. Although usually single, multiple simple adenomas do occur (Fig. 2327). The consistence is moderately firm. The cut surface is usually smooth and homogeneous, reddish-brown to reddish-yellow.

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* I am indebted to Dr. W. F. Whitney, curator of the Warren Museum of Harvard University, Dr. J. H. Wright, director of the Clinico-Pathological Laboratory of the Massachusetts General Hospital, and Dr. F. T. Fulton, pathologist to the Rhode Island Hospital, for the use of their collections.

Secondary changes are common. The colloid frequently becomes increased in amount. The walls of adjoining distended vesicles rupture or are atrophied by pressure, and cysts are formed. Thus the tumor becomes changed into a *colloid goitre* (Fig. 2328). With continued production of colloid these cysts may reach a large size, and the tumor is then spoken of as a *cystic goitre*. The cysts may be single or multiple. Their contents are frequently tinged with blood or contain modified blood pigment. I cannot agree with Bradley, however, that the cysts are usually hemorrhagic in origin. Müller states that in the colloid goitre the capillaries are diminished in number. The intima of the arteries is usually thickened and the elastic tissue is degenerated (Jores).

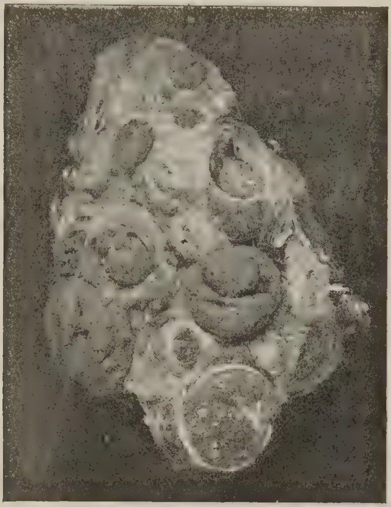

FIG. 2327.—Multiple Simple Adenomas of the Thyroid Gland. (Natural size.)

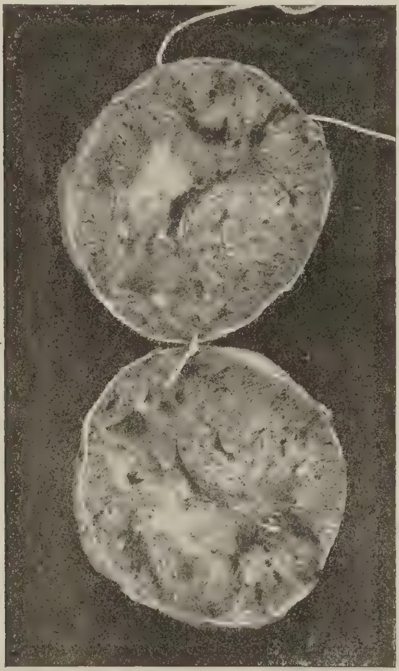

FIG. 2328.—Colloid Goitre. The vesicles are greatly distended with colloid forming small cysts; the largest are 0.5 cm. in size. The colloid in some of the cysts is tinged with blood. (Natural size.)

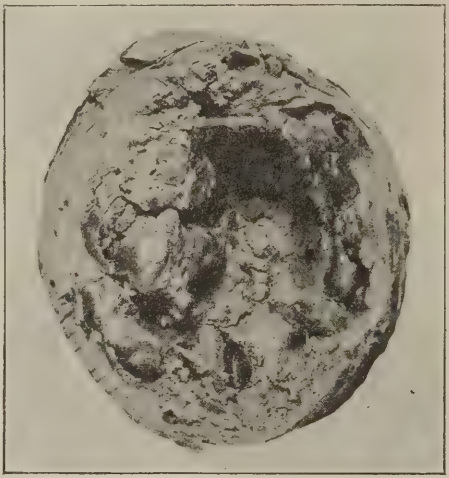

FIG. 2329.—Fibrous Goitre which has Undergone Central Softening. The cyst measures 5 cm. in diameter, and has a shaggy lining composed of necrotic tissue. (Warren Museum, No. 9721.) (Reduced.)

The stroma varies greatly in amount. It may form broad areas or bands of fibrous tissue, or the tumor may be largely converted into fibrous tissue and form a *fibrous goitre*. The vesicles are shrunken and separated by wide areas of fibrous tissue (Fig. 2330). The overgrowth of fibrous tissue is probably secondary to the degeneration and atrophy of the glandular tissue. This fibrous tissue, usually dense and sclerotic, is prone to undergo hyaline degeneration. Gutknecht pointed out that large cysts are sometimes formed by the softening of this degenerated fibrous tissue. A good example of a fibrous goitre that has undergone central softening is contained in the

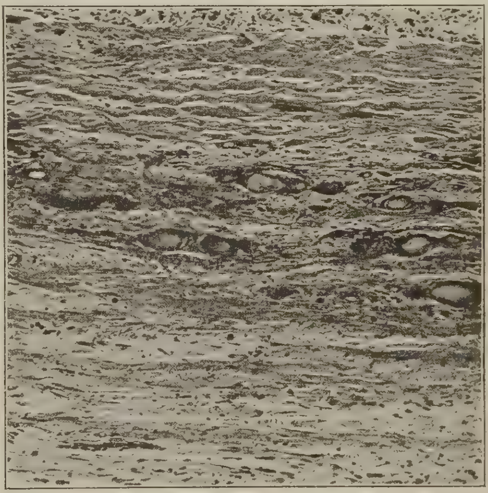

FIG. 2330.—Fibrous Goitre. It is composed of dense hyaline connective tissue. A few atrophied vesicles containing colloid are seen. (× 86 diam.)

Warren Museum (Fig. 2329). This unilocular cyst measures 5 cm. in diameter. Its wall, which is 1.5 cm. in greatest thickness, is formed of dense, hyaline fibrous tissue. Fig. 2330 is a section of the wall. These cysts of softening usually contain a turbid fluid composed of cellular and fatty detritus, broken-down red blood corpuscles, polynuclear leucocytes, blood pigment, calcium oxalate, and cholesterin crystals.

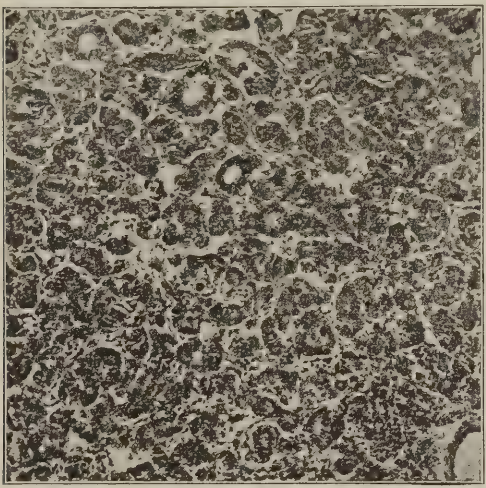

FIG. 2331.—Fœtal Adenoma of the Thyroid. The cells are arranged in solid masses and in circles surrounding small spaces. No colloid. Stroma very vascular. (× 85 diam.)

Lime salts are commonly deposited in the walls of old cysts. Large calcified plates may form. I have seen a cyst about 5 cm. in diameter the wall of which was entirely calcified. Bone has been found in the same situation. Lücke reported two cases in which there was typical bone formation with bone corpuscles and medullary spaces.

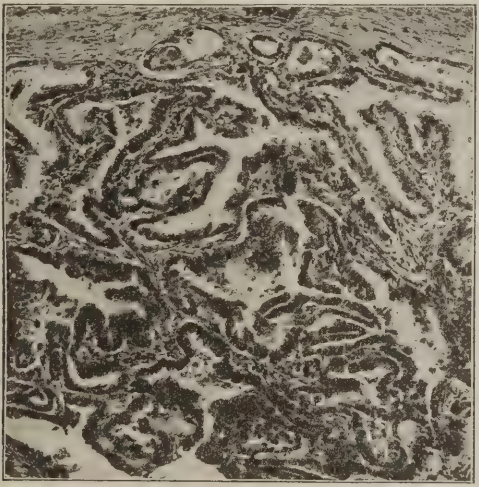

FIG. 2332.—Papilliferous Adenoma of the Thyroid. Branching processes, consisting of a connective-tissue framework covered with columnar epithelium, lying within a cyst. (× 73 diam.)

Extensive amyloid infiltration of the vessels has been observed by Friedreich, Virchow, and others. The entire tumor may assume a waxy appearance, hence the term *waxy* goitre applied by Beckmann.

Fœtal Adenoma (Fig. 2331).—The structure resembles that of the fœtal thyroid. The cells are arranged in solid columns and in circles surrounding small spaces. There may be a few vesicles, but there is little if any colloid. Occasionally the tumor is not sharply circumscribed, but usually it is provided with a definite capsule. The stroma is generally scanty, but is sometimes moderately abundant, and may be the seat of a mucoid degeneration (*Adenoma myxomatosum*, Wölfler). In size fœtal adenomas vary from a few millimetres to four or more centimetres, and are usually multiple, grayish-

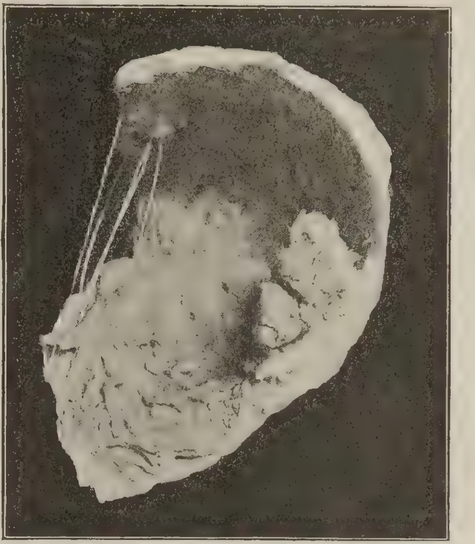

FIG. 2333.—Papilliferous Adenoma Developing from the Wall of a Thyroid Cyst. (Natural size.)

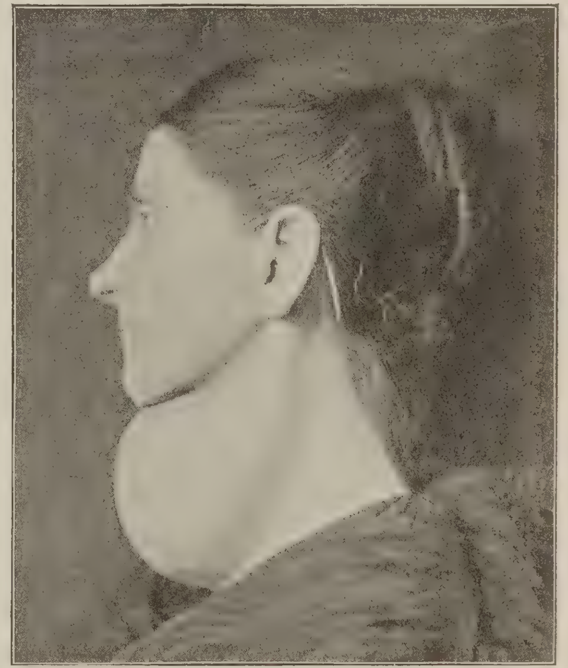

FIG. 2334.—Papilliferous Adeno-cystoma Successfully Removed by Dr. F. B. Lund at the Boston City Hospital. (Reduced in size.)

white or reddish in color, and of soft consistence. Often they are very vascular. They generally develop at the time of puberty (Wölfler).

Papilliferous Adenoma (Fig. 2332).—There are two types: (*a*) the papilliferous adenoma which develops from the walls of old cysts; (*b*) the true cystoma which closely resembles the papilliferous adeno-cystoma of the ovary. This important class of thyroid tumors lies on the border-line between the benign and the malignant growths.

Wölfler was the first to study them carefully; but all his cases were examples of papilliferous epithelial ingrowths from the walls of preformed cysts. Such a tumor is pictured in Fig. 2333. The second type of papilliferous growth is shown in Fig. 2335. It is a very rare form. I have not found it described in the literature. My collection includes two cases, which are quite similar in appearance. The one photographed in Fig. 2334 was successfully removed by Dr. F. B. Lund at the Boston City Hospital. It was surrounded by a fibrous capsule. It will be described by Dr. H. C. Low in the Medical and Surgical Reports of the Boston City Hospital, 1901. Dr. Low has searched through the museums of the London hospitals, which are rich in thyroid tumors, but has not found a single example of this type.

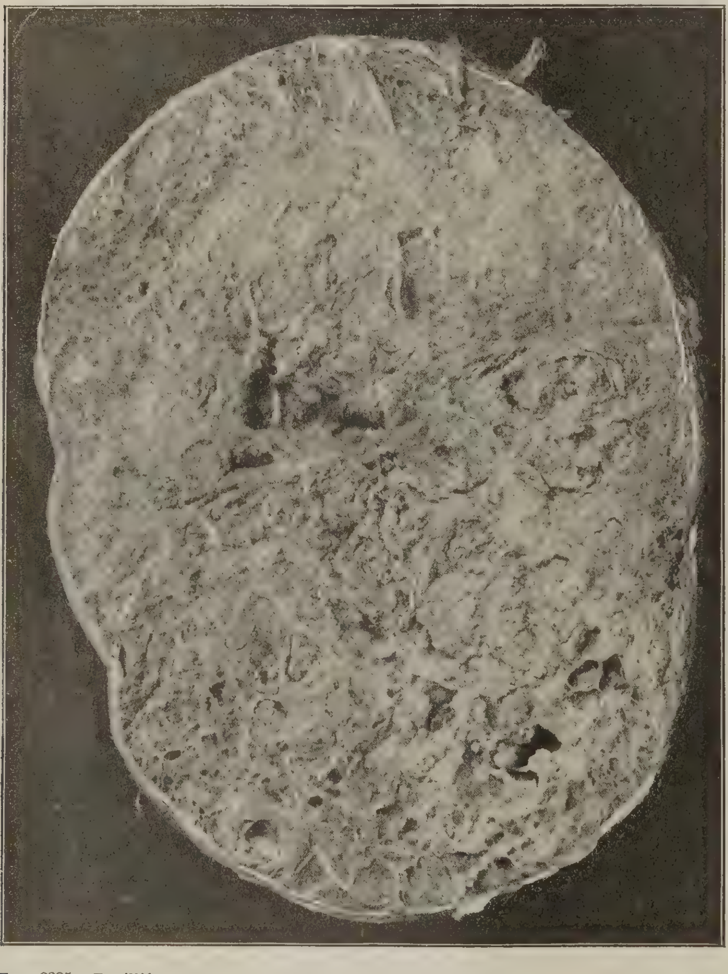

Fig. 2335.—Papilliferous Adeno-cystoma. (Natural size.) There are dendritic ingrowths into cystic spaces. The appearance of the tumor before removal is shown in Fig. 2334.

The papilliferous tumors consist of branching processes lying within a definite cyst or cystic spaces. The growth is composed of delicate connective-tissue stalks covered with cuboidal or columnar epithelium. There is rarely any colloid formation, but occasionally a vesicle is seen containing colloid. The stroma may undergo mucoid degeneration. Sometimes the tumors assume malignant properties and invade the surrounding tissues. In a papilliferous growth which developed on the inner wall of a cyst (Fig. 2333) I have seen numerous mitotic figures. Just as the fibrous wall of ovarian cysts frequently prevents the extension of adenocystoma into the peritoneal cavity, so in this thyroid tumor the wall of dense fibrous tissue acted as a barrier to prevent the infiltration of the neighboring structures.

The coalescence of simple colloid cysts may give rise on naked-eye examination to the false impression of papilliferous intracystic growths.

Goitres have frequently a rich blood supply. Fœtal adenomas are especially vascular. The term *vascular goitre* is frequently used. I agree with James Berry that the term is a bad one and should not be employed. He says: "If it be intended to signify a goitre composed mainly of blood-vessels, then it is a name for what probably does not exist, for there is no evidence of the existence of any such goitre."

Morbid Anatomy.—The size of thyroid tumors varies from small nodules, 1 cm. or less in size,* to masses as large as a man's head (Alibert, Keser). Such monstrous enlargements are, however, very rare, and probably are seen only in regions where the endemic disease abounds. In this country the endemic goitres are of small size and would attract little attention in Switzerland. The thyroid tumors that I have examined in Massachusetts have rarely measured more than 8 cm. in diameter. The tumor depicted in Figs. 2334 and 2335 is one of the largest in my series. The tumors generally occur singly, but they may be multiple. There is not uncommonly a diffuse enlargement of the entire thyroid, but usually one lobe is affected. The right is more frequently involved. Brunet seeks to explain this predisposition on the ground that the venous outflow is normally more impeded from the right lobe than from the isthmus or left lobe. Tumors from the isthmus are rare. A photograph of a specimen in the Warren Museum is shown in Fig. 2336.

The thyroid growths which develop anteriorly are visible on inspection even when they are of small size. Tumors growing posteriorly from the lateral horns may produce pressure symptoms before their existence has been discovered. They may form *retro-œsophageal goitres* which frequently escape detection.

Adami performed an autopsy on a woman who died quite suddenly from dyspnœa. She had suffered from previous paroxysmal attacks supposed to be asthmatic. Adami found that the trouble was due to a localized enlargement of the thyroid.

Large tumors sometimes fill up the space between the chin and the sternum. Huge pendulous goitres have been described which projected over the front of the sternum to below the level of the xiphoid cartilage, and instances are on record of goitres that have reached as low as the waist (Alibert). In a case published by P. Bruns the weight of the tumor produced lordosis in the cervical and kyphosis in the thoracic region of the spine. The tumor measured 70 cm. in greatest circumference. These enormous goitres are probably always cystic. The pendulous goitres are connected with the thyroid by a band of parenchymatous or connective tissue which carries blood-vessels.

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* I have seen a discrete nodule, with the structure of a fœtal adenoma, which was only 2 mm. in size. Wölfler would probably regard it as an embryonic rest.

Tumors developing from the tip of a lateral lobe may appear in the submaxillary region near the angle of the jaw. The nature of these *submaxillary goitres* and their connection with the thyroid has often remained unrecognized. Tumors of the isthmus lie in the median line in front of the trachea. Those arising from a lateral lobe by pushing the trachea to one side may also take up a position in the middle of the neck.

The substernal and intrathoracic goitres form an important class. They are usually connected with the lower part of *the lateral lobes* or *the isthmus.* Some thyroid tumors grow down behind the sternum into the anterior mediastinum. The substernal goitre is the *goître plongeant* of the French. They are a very dangerous class of tumors. Owing to their situation they frequently cause severe dyspnœa by pressure on the trachea. Sometimes they become visible only during expiration, sometimes they lie entirely behind the sternum. A peculiar form of substernal tumor is the "wandering goitre" described by Wölfler. The tumor in his case did not rise and fall during respiration, but at times it actually changed its position. It was a small tumor, and when it migrated into the thorax it could be neither seen nor felt, but it produced severe dyspnœa by pressure on the trachea and circulatory disturbances by pressure on the right innominate vein. Reuter had a somewhat similar case. The tumor developed from the right lateral lobe. Upon coughing it rose above the sternum.

McWhinnie described a goitre which descended behind the sternum as low as the bifurcation of the trachea. Retrosternal goitres, as a rule, however, do not extend so deeply into the thorax and are not so large as those that grow beneath the clavicle. The latter may attain an enormous size and greatly compress the lung. Dittrich found a large thyroid cyst nearly filling the right pleural cavity. Above the cyst was thyroid tissue. The right lobe of the thyroid gland was missing.

These intrathoracic growths arise as follows: 1. Thyroid tumors may grow downward into the chest. 2. Tumors may develop from thyroids which are situated abnormally low in the neck. Kocher has introduced the term "thyreoptosis" for a condition analogous to other splanchnoptoses. 3. Tumors may arise from congenital prolongations downward of the thyroid gland (Krönlein). 4. Tumors may develop from accessory thyroids.

The first mode of origin is the most common (Braun). Usually a parenchymatous pedicle, it may be a thin one, connects the tumor with the thyroid gland. The connecting band may disappear or become converted into fibrous tissue. Then the genesis of the tumor cannot be determined. It seems wise, however, as Wölfler says, to classify all thyroid tumors which are not connected with the main thyroid, without regard to their genesis, as accessory goitres. No suspicion may be held that a tumor from the pleural cavity is thyroidal in nature until microscopic examination has been made. Virchow cites such a case. These accessory thyroid tumors situated within the pleural cavity are of course rare. Osler and F. A. Packard have reported cases. Reference has already been made to Dittrich's famous case.

Accesory thyroid tumors of the neck may develop from any of the accessory thyroid glands which are so common in the neighborhood of the main thyroid. They are usually found near the hyoid. Rokitansky and Sir James Paget first described them in the middle of the last century. One case has come under my notice in the post-mortem room of the Boston City Hospital. It was a simple adenoma measuring 2.5×2×1.5 cm. situated above and to the left of the thyroid and 1 cm. from it. There is no other case in the pathological records of the hospital. Pollard found a papilliferous adenoma of an accessory thyroid of the neck.

Intralaryngeal thyroid tumors are very rare; Paltauf reported a case in 1891. The tumor was situated under the right vocal cord. On post-mortem examination it was found to be composed of thyroid tissue and to be connected with the thyroid gland. Baurowicz in 1898 collected eight cases in which tumors composed of thyroid tissue had been observed within the larynx and trachea, and added one of his own. He thinks these tumors arise from the thyroid and are enabled to grow into the trachea owing to a congenital defect in the wall. Bruns, however, has described a tracheal tumor which originated from an accessory thyroid in this situation.

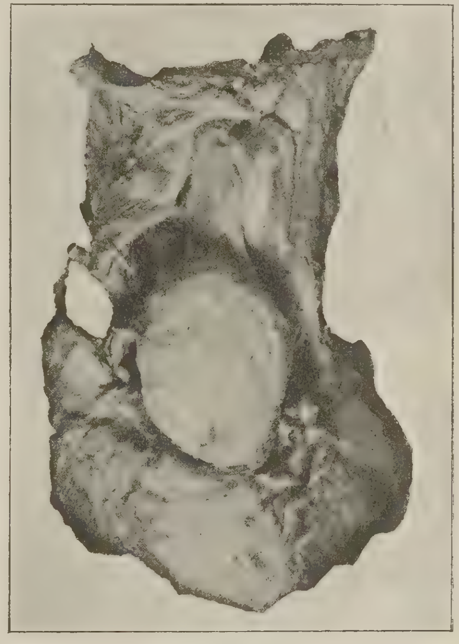

Fig. 2336.—Tumor of the Isthmus of the Thyroid. It extends upward as far as the lower border of the thyroid cartilage. (Warren Museum, No. 7,747.) (Slightly reduced.)

Accessory thyroid tumors occur in the base of the tongue. I have collected eleven cases from the literature,* and there is an unrecorded case in the Warren Museum. It is a nodule 1.5 cm. in size, and was removed by Dr. S. J. Mixter. In 1892 Dr. J. C. Warren presented a case before the American Surgical Association. These tumors have also been studied by Butlin, Wolf, and Watson. They are usually 2 to 3 cm. in diameter. Nearly all the cases have been in women. In Wolf's case the tumor produced great dysphagia.

Symptomatology and Diagnosis.—It is usually not difficult to determine whether or not a tumor of the neck is connected with the thyroid. The thyroid is closely bound to the larynx, and moves with it during deglutition. It must be remembered that any tumor or swelling connected with the outer surfaces of the larynx or trachea may present this sign. Berry tells us that a lipoma attached to the thyroid cartilage was mistaken by Sir Morell Mackenzie for a thyroid cyst. It moved with

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*Theisen (*Albany Medical Annals,* October, 1901) reported a case of a tumor at the root of the tongue which he regarded as an accessory thyroid. It cannot, however, be included in the list as the structure of the tumor was not determined.

the larynx. Tumors thus simulating growths of the thyroid are, however, very rare.

A very large goitre may fail to move during deglutition. Either the bulk of the tumor may prevent the movements of the larynx or the tumor may become united to neighboring structures so that its position is fixed. The latter is frequently the case with malignant neoplasms.

The shaking or tilting of large thyroid tumors during deglutition is stated by Berry to be almost as valuable a sign as the rising of the tumor.

Dr. Osler reported a case of lymphosarcoma of the deep cervical glands which involved the thyroid and simulated goitre.

A tumor of the thyroid usually displaces the sternomastoid muscle outward and forward, while other tumors of the neck which might be mistaken for goitre generally push this muscle to the inner side (Berry).

The position of the carotid artery is an important aid in diagnosis. Bronchoceles push the artery backward and outward. The reason is plain. The thyroid gland is situated to the inner side and slightly anterior to the carotid sheath. Mr. Jonathan Hutchinson, in a recent clinical lecture on a case of tumor of the neck, laid special stress upon the position of the carotid, which was in front of the growth, in distinguishing it from goitre.

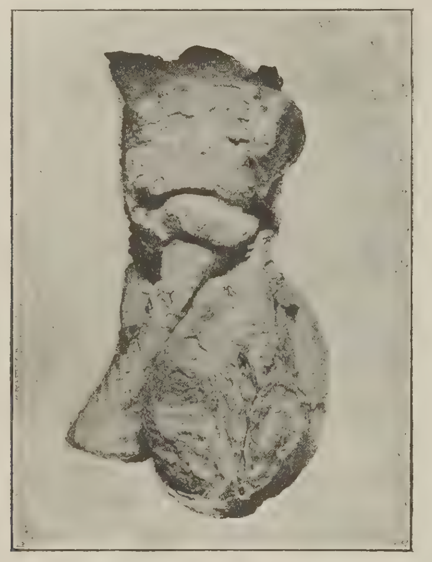

FIG. 2337.—Trachea Displaced and Compressed by a Tumor of the Left Lobe of the Thyroid. (Warren Museum, No. 7,979.) (Slightly reduced.)

The internal jugular frequently is carried forward and may lie in front of a thyroid tumor. The carotid artery and jugular vein thus become widely separated. The position of the jugular is due to the traction of the veins which pass to it from the thyroidal plexus (Lücke).

Pulsation transmitted to the tumor from the carotid artery has led to the mistaken diagnosis of aneurism. Guttmann stated that in the goitres of Graves' disease there is an arterial murmur over the tumor which is not present in other forms of goitre. George Dock says he has not seen a case of simple goitre in which there was a murmur. James Berry, however, reports cases in which loud murmurs were audible over the tumor, and further states that a well-marked bruit is not uncommon.

The consistence of benign thyroid tumors varies greatly. The simple adenomas are usually soft. Tense cysts and fibrous goitres may be very hard, and goitres infiltrated with lime salts are, of course, hardest of all. Beck has called attention to the Roentgen rays as a means of diagnosing calcified goitres. In dealing with suspected cystic growths, tapping gives the surest means of diagnosis. Strict attention should be paid to asepsis, and care taken to avoid blood-vessels.

Pressure on the large veins of the neck produces obstruction to the venous circulation and roaring in the head, vertigo, deafness, etc., may result. These symptoms are rare.

Pressure on the recurrent laryngeal nerve may lead to paralysis of a vocal cord. A subclavicular goitre may produce numbness or pain in the arm by pressure on the brachial plexus. Involvement of the cervical sympathetic is rare.

The trachea is frequently displaced to one side, and lateral compression is common (Fig. 2337). Rose taught that the tracheal rings were often atrophied and softened; subsequent investigators have failed to confirm his observations. The stenosis of the trachea may be marked. Extreme lateral flattening gives the trachea very much the shape of a sword scabbard. The brassy cough due to compression of trachea or bronchus is well known and characteristic. Dyspnœa is the most common symptom of goitre. It is usually the result of direct pressure upon the trachea.

Compression of the œsophagus leading to dysphagia is not common. It occurs especially in those rare cases in which a prolongation of a goitrous gland extends behind the pharynx and œsophagus, or between the trachea and the œsophagus. I have seen a goitre which nearly encircled the larynx and trachea. There may be a marked inward bulging of the pharyngeal wall caused by the thyroid tumor. Edwards records a case of acute thyroid enlargement in which the dysphagia was extreme and death partly due to starvation.

A simple goitre does not produce constitutional symptoms. Walter Edmunds states that cases of goitre which present symptoms other than those due to pressure are really examples of Graves' disease.

The diagnosis of intrathoracic goitre is very difficult. Kocher in his latest article (*Archiv f. klin. Chir.*, 1901, vol. lxiv., p. 454) gives the following signs:

1. Patients have a strongly marked dyspnœa, out of all proportion to the relatively small struma in the neck. The dyspnœa may take the form of a constant air-hunger or of intermittent attacks of suffocation.

2. The trachea is pushed to one side, much farther than can be explained by the tumor of the neck. Indeed, it can happen that the trachea is pushed to that side on which the cervical portion of the thyroid appears enlarged.

3. The tumor in the neck is not definable below; on the other hand, one feels a distinct resistance on pressing the fingers deep into the thoracic aperture, and this resistance is often accompanied by a heaving pulsation.

4. The portion of the tumor in the neck can neither be deeply pressed into the thorax nor pulled upward. The trachea and larynx also are less easily drawn upward than normal.

5. There are signs of pressure upon the great veins of the neck, indicated by stasis which finds no satisfactory explanation in the tumor demonstrable in the neck. The cervical veins fill from below if one empties them, by pressing the blood out with the finger, and the veins of the arm no longer empty, in marked cases, when the arm is elevated. Headache, dizziness, tinnitus, epistaxis, and loss of memory may direct attention to the stasis in the cerebral veins.

6. Paresis of the recurrent laryngeal nerve is not uncommon, and quite often there is paralysis of the sympathetic of the same side with retraction of the optic bulb, slight ptosis, a narrow palpebral fissure, and myosis.

Birch-Hirschfeld found at a necropsy an intrathoracic goitre which had given rise to the symptoms of a severe cardiac neurosis.

Dulness on percussion is rarely elicited over intrathoracic goitres (Braun).

COMPLICATIONS.—In cysts of no other organ is there such a tendency to *hemorrhage* as in those of the thyroid

(Berry). Serious or fatal results may follow. Dr. Osler records a case in which death was due to hemorrhage into a large bronchocele. The cyst had ruptured, and the blood had infiltrated the surrounding tissues and extended beneath the sternum into the anterior mediastinum.

Rupture of a cyst into the trachea or larynx may lead to sudden death from suffocation.

Inflammation of a thyroid tumor may occur. The term "strumitis" is applied to an inflammation of a goitrous gland, while "thyroiditis" refers to an inflammation occurring in a normal gland. The former is the more common. The infection is usually secondary to primary infection elsewhere. Strumitis and thyroiditis occur more frequently in association with typhoid fever than with any other disease. Metastatic inflammation of the thyroid may take place in pyæmia, puerperal fever, pneumonia, and other infectious diseases. It is also said to be associated with rheumatism and malaria.

Tavel made a bacteriological examination in eighteen cases of strumitis. All but three were secondary infections. Streptococcus pyogenes was the micro-organism most frequently found. Diplococcus lanceolatus, Staphylococcus pyogenes, Bacillus typhosus, and Bacillus coli were also isolated, usually in pure culture. In the three primary cases no bacteria were demonstrable. Treatment of goitres by injection has not infrequently been the cause of strumitis.

The inflammations terminate in resolution, abscess formation, or gangrene. Abscess formation is the most common.

Strumitis can be recognized by the usual signs and symptoms of inflammation of the external parts. A rapid increase in the size of the thyroid occurs. The other important symptoms are dyspnœa, dysphagia, and fever. Pain is frequently severe. There is localized congestion and œdema of the surrounding tissue, and the tumor may become adherent to the overlying skin, but a thyroid abscess rarely opens externally.

An abscess may rupture into the œsophagus, or more commonly into the trachea. Sir James Paget describes a case in which a large suppurating thyroid cyst burst into the pharynx and produced suffocation.

Treatment.—Some of the simple adenomas (parenchymatous and colloid goitres of authors) can be cured by medical treatment. The most favorable cases are those occurring in the young. All the fœtal and papilliferous adenomas, as well as the majority of simple adenomas, require the surgeon's knife for their removal.

If the patient is suffering from an endemic goitre he should leave the affected district. A residence at the seaside is said to be most beneficial. In a locality where goitre abounds the drinking-water should be boiled as a prophylactic measure.

The medical treatment may be local, general, or specific (organotherapy). The local treatment consists of the use of ointments and injections. The red iodide of mercury ointment is recommended. It should be rubbed into the skin over the tumor daily until the skin is tender. After a few days the procedure should be repeated. Exposure of the skin to the sun's rays after the ointment has been applied favors the remedial action.

Some authorities strongly recommend treatment by injections; others strongly condemn it. Injections of iodine should not be employed, as suppurative inflammation has frequently followed its use. Iodoform may be used, but strict aseptic precautions should always be taken. Mosetig-Moorhof recommends the following emulsion: iodoform, 1 part; ether, 7 parts; olive oil, 7 parts. Inject about ♏ xv. once every five or eight days. Frey treated sixty-five cases by this method with no untoward results. Nicholas Senn advocates injections of a five-per-cent. solution of carbolic acid, repeated once or twice a week.

Many internal remedies have been recommended. Most of them are useless. Iodine is probably the most valuable. It may be given as potassium iodide in doses of gr. v.–xx., or as tincture of iodine in doses of ♏ v.–x. two or three times a day (Murray). Ferrand, Gautier, and others have called attention to the particular susceptibility of goitrous individuals to iodism. Kocher states that he has had a number of patients brought to him with a diagnosis of acute thyroidismus when their symptoms were entirely due to iodine poisoning.

Phosphorus is highly lauded by Kocher. Experimental studies show that administration of phosphorus causes a notable increase in the iodine content of the thyroid.

It is still an open question whether thyroid extract yields any better results than iodine. Kocher thinks not. Bruns, Angerer, Murray, and others obtained striking results in some cases. Improvement is common, cure is rare. Reinbach fed thymus gland with almost equal success. Murray (*Edinburgh Medical Journal*, 1900, vol. viii., p. 113) administers dry thyroid in doses of three or more grains two or three times a day, or the liquid extract in doses of ♏ xv. In cases in which operation is deemed advisable he recommends treatment by thyroid extract for two or three weeks. The reduction in size of the goitre and superficial veins makes its removal less difficult.

Treatment of Strumitis.—An ice-bag should be applied to the gland in the early stages of the disease. The bowels should be cleared by a dose of calomel. If an abscess forms it should be incised without delay.

Malignant Tumors.—Both primary and secondary tumors of the thyroid are very rare. Cooper in 1819 wrote that cancer of the thyroid never occurs. Walshe estimated the frequency of thyroid to other cancers as 1 to 1,000. Tanchon found among 9,118 cases of cancer only 8 in which the thyroid was involved. Cancer of the thyroid occurred 11 times in 7,700 autopsies (Chiari). Malignant disease of the thyroid is more common in goitrous districts than elsewhere. Lücke observed 10 cases in two years in Berne.

Cancer is more common than sarcoma. The relative frequency of cancer to sarcoma, judging by collected statistics, is as three to one.

Lartigau (*Am. Jour. of the Med. Sci.*, August, 1901) collected fifty-five cases of primary sarcoma of the thyroid. It is a disease of the old rather than the young. Few cases occur under forty years. The earliest age was eleven years. It is more frequent in the male than in the female (Morf).

The round-celled sarcoma is the most common. Ten of the forty cases collected by Morf were of this variety. Spindle-celled, mixed-celled, and alveolar sarcomas occur.

The tumors may vary in size from a small nodule 1 or 2 cm. in diameter to a mass the size of a child's head. They have a smooth or slightly lobulated contour, and on section are usually pale, smooth, and translucent. Their consistence is soft and homogeneous. They are more vascular than the carcinomas. In the majority of cases they have originated in the right lobe (Lartigau).

Sarcoma of the thyroid ordinarily grows more rapidly than carcinoma. Death usually occurs within a year (Lücke). It is often induced by compression or infiltration of the trachea or œsophagus.

Metastases were present in forty-five per cent. of the cases of sarcoma collected by Morf. The cervical lymph nodes are most frequently involved in sarcoma as well as in cancer. Secondary growths in the lungs and bones are common. The great vessels of the neck may become infiltrated. Wölfler records a case in which the tumor invaded the internal jugular and extended downward through the left innominate and superior vena cava into the heart.

About one hundred and fifty cases of primary cancer of the thyroid have been recorded. The majority of these have been published within recent years. Hinterstoiser found fifty cases in the records of Kundrat's Pathological Institute at Vienna. In 1899 Poncet published forty-seven cases which he personally observed in Lyons, a city in which endemic goitre is commonly seen.

The size and appearance of the carcinoma vary greatly. In the majority of cases the tumor has been of small size. The thyroid gland is sometimes actually diminished in size. Before the growth has infiltrated the surrounding tissues it may closely simulate a benign encapsulated tumor.

Various types of cancer occur. The *papilliferous adenocystoma* may take on a low degree of malignancy and would then be classed as a cancer. Cases of this nature have been described by Barker and Wölfler.

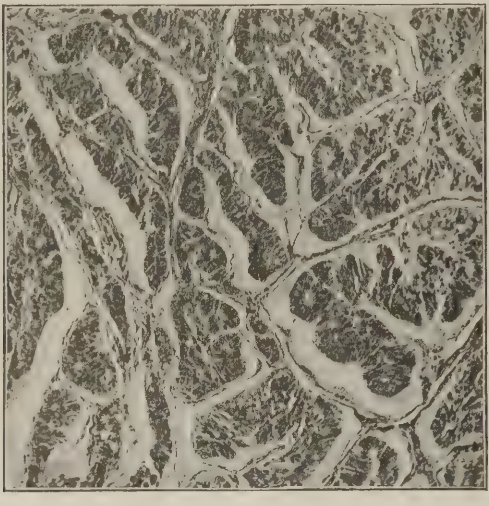

FIG. 2338.—Cylindrical-celled Carcinoma of the Thyroid. Acini filled with high cylindrical epithelium; no colloid present. (× 86 diam.)

A rare but interesting form is the *cylindrical-celled carcinoma.* The high cylindrical-celled adenomas probably are always malignant, although in places their histological structure may not suggest it. Fig. 2338 is from a cylindrical-celled adenoma that invaded the trachea.

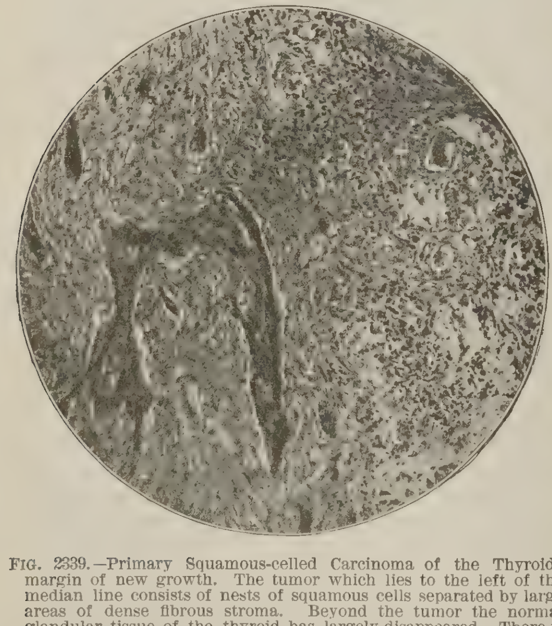

FIG. 2339.—Primary Squamous-celled Carcinoma of the Thyroid; margin of new growth. The tumor which lies to the left of the median line consists of nests of squamous cells separated by large areas of dense fibrous stroma. Beyond the tumor the normal glandular tissue of the thyroid has largely disappeared. There is marked infiltration with lymphoid cells. One shrunken vesicle filled with colloid is distinctly seen. (× 86 diam.)

The *squamous-celled* is also a rare but well-recognized form of primary thyroid carcinoma. It has been described by Forester, Lücke, Kaufmann, and Wölfler. Fig. 2339 is from a case that was examined by Dr. J. Homer Wright, of the Massachusetts General Hospital. It is held that this peculiar tumor originates from the remains of the branchial clefts which are enclosed within the thyroid.

Housell has collected twelve cases of benign thyroid tumors that formed metastases. I have found two other cases in the literature. The original tumor as well as the secondary growths in all the cases had the structure of simple adenomas. Metastases in the bones have been a constant occurrence, and they usually form pulsating tumors. The first case was studied by Cohnheim. The thyroid tumor was of moderate size, and there were metastases in the bones, lungs, and bronchial lymph nodes. A nodule of the original tumor projected into the lumen of a small vein. Riedel, and Oderfeld and Steinhaus (*Cent. f. allg. Path. u. path. Anat.*, 1901, vol. xii., p. 209) have described cases in which the thyroid gland was normal. The latter hold that normal thyroid tissue may grow into blood-vessels, and the epithelial cells swept along in the current form metastases in the bones. Christiani (*Jour. de phys. et path. Anat.*, 1901, vol. iii., p. 22) has demonstrated the great vitality and viability of thyroid tissue.

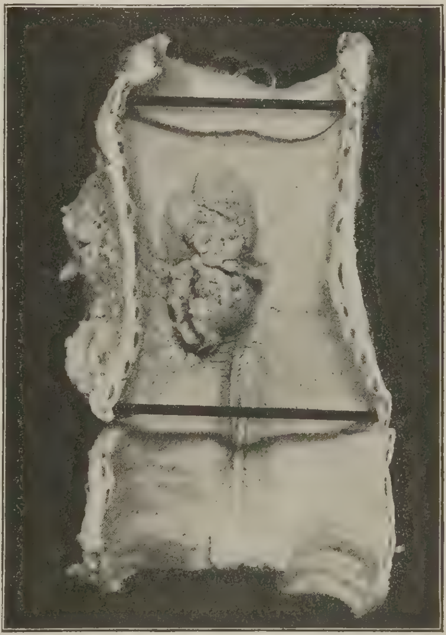

FIG. 2340.—Carcinoma of the Thyroid which has Invaded the Trachea and Formed a Button-like Nodule which Projects into the Lumen. (Warren Museum, No. 4,892.) (Natural size.)

SYMPTOMATOLOGY AND DIAGNOSIS.—Clinically it is difficult to distinguish between sarcoma and carcinoma. The latter usually are of smaller size and develop more slowly.

The malignant tumors develop rapidly. Pain is an early and important symptom. It is usually severe and radiates to the head or shoulders. Tenderness on pressure is often present. Fever is the rule. Enlargement of the lower cervical lymph nodes is strong evidence of the malignant nature of the thyroid tumor, provided strumitis can be ruled out. Immobility of the tumor does not occur until the capsule of the thyroid has been penetrated and the tissues of the neck are infiltrated. Hence it is a late sign. Kaufmann considers thrombosis of the veins of the neck one of the most reliable signs of malignant tumors.

Penetration of the trachea is common. An elevated nodule, sometimes of considerable size, is found projecting into the lumen. It is usually situated about 2 cm. below the cricoid. Fig. 2340 is from a specimen in the Warren Museum of the Harvard Medical School. The patient entered the Massachusetts Hospital suffering from extreme dyspnœa, hoarseness, and some dysphagia. Dr. Knight examined the larynx and found paralysis of one posterior crico-arytenoid muscle, and made out an obstruction of the trachea. The dyspnœa continued until death occurred two days later. The autopsy was performed by Dr. Fitz. A tumor mass the size of a small lemon connected with the thyroid was found. The growth extended through the anterior wall of the trachea projecting into the lumen to such an extent as to reduce the calibre fully two-thirds. The œsophagus was so compressed as barely to admit the little finger.

A peculiar chronic inflammation of the thyroid which closely simulates an infiltrating tumor has been described and studied by Riedel, Tailhefer, and Berry. A number of cases have been reported within the past five years.

Treatment.—Early and radical operation offers the only hope of cure.

Tuberculosis.—Although rare, tuberculosis of the thyroid is more common than is generally stated. Chiari found the thyroid was involved at autopsy in seven out of one hundred cases of tuberculosis. Roger and Garnier (*Arch. gén. de méd.*, 1900, vol. iii., p. 385) assert that while tubercles rarely develop, a sclerosis of the gland is a constant feature of chronic tuberculosis of the lungs or elsewhere.

Syphilis.—Swelling of the thyroid is common in the early stages of syphilis. Engel-Reimers found the gland enlarged in fifty per cent. of the cases. Gumma is extremely rare. The few instances that have been recorded were nearly all in children, and usually associated with severe visceral manifestations of the disease. For details in regard to syphilis of the thyroid the monographs of Fürst and Küttner may be consulted.

Echinococcus Disease.—Berry has collected twenty-two cases. A single cyst has usually been found. The tumor when large may be very irregular in shape. The symptoms are those of an ordinary goitre. Dyspnœa is usually present. There is a tendency to spontaneous suppuration. Diagnosis can be made only after microscopical examination of the cyst contents. The aspiration of a clear, limpid, colorless fluid is suggestive (Berry). The demonstration of hooklets or scolices confirms the diagnosis. The known association of urticaria with hydatid led Lannelongue to make the correct diagnosis. Perforation into the trachea has caused suffocation in a number of instances. *Joseph Hersey Pratt.*

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GOITRE AND CRETINISM.

—Definition.—Cretinism is a peculiar type of mental and physical degeneracy, either congenital or developing in childhood, due to absence or disturbance of the function of the thyroid gland. An individual afflicted with cretinism is called a cretin.

Etymology.—The etymology of the word cretin is shrouded in obscurity. It seems that the word originated as a colloquialism in the Canton of Wallis in Switzerland. Esquirol (quoted by Demme, "Ueber den endemischen Kretinismus," Berne, 1840) derives the term from an old word *cretine*, an inundation (Anschwemmung), and connects it with the marshy character of many cretin districts. There is, however, no proof of such a derivation. According to Fodéré, the word comes from *chrétien*, a Christian, the term, "bon chrétien," having formerly been applied to the cretin, on account of his contented disposition. Another interpretation, according to which the word is also derived from chrétien, is based upon the fact that cretins were popularly believed to be elected Christians, and were considered holy, inasmuch as they were supposed to fulfil the lofty function of expiating in their unhappy lot the sins of their fellowmen. According to Gross ("Ueber die Ursachen des endemischen Kropfes und des Kretinismus." Inaugural Dissertation, Tübingen, 1837), the word comes from *Christiani* (spelled *Chrestiani* by Tertullian), because the Romans looked upon the converts to Christianity as fools and imbeciles. Celsus also spoke of the Christians as a society of slaves and idiots. Some have traced the term cretin to a word *cretina*, meaning stupid or silly. According to Ackermann, cretin comes from a Romance word, *cretira*, a creature. Others have derived it from *creta*, chalk, on account of the chalky complexion of the cretins. This derivation finds some support in the German colloquial word for cretin; viz., *Kreidling*, from *Kreide*, chalk.

Nearly every locality has its special name for cretins. In Austria they are known as Trotteln or Gacken; in Germany, as Kretins or Kreidlings; in German Wallis, as Gauche, Tampe, or Nollen; in French Wallis, as Crétins, or as Marrons, on account of the dark color possessed by some; in Salzburg, as Fexen, Trepped, or Trutsched; in Würtemberg, as Dackel, Dippel, Tralle, or Simpel; in the Pyrenees, as Cajots or Capots; in Piedmont, as Pazzi;

in Italy, as Gavas, Totolas, or Cristiani; in South America, as Bovos or Tontos. In Latin writings the word Christiani is generally employed.

Synonyms of Cretinism.—The synonyms of cretinism are infantile myxœdema, cretinoid idiocy; in French, idiotie avec cachexie pachydermique, pachydermie crétinoide.

Historical.—According to the Sardinian Commission's Report, the first mention of a cretin occurs in the fifteenth century. Demme (*loc. cit.*) says that the first reliable mention is in the writings of Peter van Foreest, a Dutch physician who lived from 1522 to 1597 (P. Foresti: "Observat. et curat. opera omnia," Francof.). A contemporaneous reference is found in the writings of Felix Plater (1536–1614) (F. Plateri: "Observat. in hominis affectibus plerisque," Basle, 1614). A description of the cretins of Wallis also occurs in the writings of Giosia Scentero (about 1574) (quoted by Gross, *loc. cit.*). One of the most graphic descriptions dates back to the eighteenth century, and is that of Horace Benedict de Saussure, the famous Alpine traveller, and the first to scale Mont Blanc ("Voyage dans les Alps," four volumes, 1779–96). The first real scientific work on the subject is that of Ackermann ("Ueber die Kretinen, eine besondere Menschen-Abart in den Alpen," Gotha, 1790). In the nineteenth century cretinism formed the theme of many writers, and the literature is now almost unlimited. Particular mention should be made of the reports of the Sardinian and French Commissions, and of the article on cretinism by Baillarger and Krishaber in the "Dictionnaire des Sciences médicales." Among the most important articles of recent date are those of Ewald, Osler, Kocher, Klebs, and Murray. An interesting picture of the cretin communities in France is to be found in Balzac's magnificent novel, "The Country Doctor."

Distribution.—Cretinism may occur in any part of the world, but there are certain limited districts in which it is an endemic disease affecting a large percentage of the population (endemic cretinism). Isolated cases of the disease (sporadic cretinism) have been observed in many widely separated places that are far removed from foci of endemicity. It is, indeed, probable that if the characteristics of the disease were universally known, some cases would be found to exist in nearly every large community.

Several observers have noted conditions in the lower animals suggestive of cretinism: thus, Müller (*Würzburg med. Zeitschr.*, 1860) speaks of cretinoid changes, particularly of the bones, in calves; and Eberth ("Fötale Rachitis und ihre Beziehung zu dem Kretinismus," 1878), of the condition in calves and puppies.

There is one very interesting feature connected with the endemicity of cretinism, namely this: cretinism is endemic in the same localities in which goitre prevails as an endemic affection. This, as we shall see, is a fact of tremendous importance in the study of the pathogenesis of the disease.

Endemic Distribution.—Cretinism is endemic in certain parts of Switzerland; in the Valais, Tarantaise, Maurienne, and in the upper valleys of the Rhone. In Germany, the foci are Würtemberg (2 cretins per 1,000 population. Schmid, *Correspondenzbl. d. ärtzl. Landesver.*, 1886), the Black Forest, and Alsace; in Austria, Salzburg (1 to 139, according to Wallmann, *Wiener med. Jahrbücher*, 1863, vol. i., p. 120), Galicia, and the Kärnthner (1 to 110) and Styrian Alps (1 to 116); in France, the Pyrenees, the Vosges, and the French Alps; in England, according to Murray ("Diseases of the Thyroid Gland," Part I., 1900), the upper valleys of the Pennine Range, the north of England, the neighborhood of Allston, Stanhope, and Kendal. In these places goitre is also endemic. Formerly (Morris, *Medical Times*, 1847, vol. xvii., p. 257), cretinism was strongly prevalent in Chiselborough, in Somersetshire; but it has died out. There are also said to be foci in Scotland and in Spain. In some portions of the Caucasus (the valley of the Zschomarski and Swanetia) (Witke, *Münchener medicinische Wochenschrift*, 1896, p. 292) cretinism prevails endemically. According to Kandaratski (Congress der russ. Aerzte, 1899), goitre and cretinism are widespread throughout Western Russia, which has many marshy districts. In Asia the disease is found in certain parts of the Himalayas, in Thibet, in Turkestan, and in Tartary. As to the occurrence of the affection in Africa, very little is known. According to Blumenbach (quoted by Gross, *loc. cit.*), the disease is found in Madagascar. In South America we find it prevalent in parts of Brazil and along the slopes of the Cordilleras. No foci of endemic cretinism exist in North America at the present time (Osler, *American Journal of the Medical Sciences*, 1893). Goitre formerly prevailed in this country, and is yet endemic in Eastern Ontario, where even the lower animals suffer from it. Demme, in his American travels, found many cases of goitre, especially in Pennsylvania, about Pittsburg, in the valleys of the Allegheny, Monongahela, and Ohio rivers, and in New York; but he saw no cretinism.

Endemic cretinism is confined to certain altitudes, being most common between the elevations of 1,300 and 2,000 feet; it is hardly ever found above the level of 3,000 feet. Its homes are not the tops of the mountains, but the dark, sheltered valleys and clefts, through which course the mountain streams.

The occurrence of goitre in dogs, hogs, cats, cattle, and antelopes has been demonstrated; but as to the existence of cretinism, little is known, with the exception of the brief reference made above.

Etiology and Pathogenesis.—As stated in the definition, the cause of cretinism is absence or disturbance of the function of the thyroid gland (athyroidism, dysthyroidism, hypothyroidism). This applies both to the endemic and to the sporadic form of the disease. The proofs of the thyroidal theory, as we may call it, are as follows:

1. The most constant lesion in cretinism is that involving the thyroid gland. In the case of the endemic form, there is generally goitre; in the sporadic, the gland is either atrophic or absent.

2. *The occurrence of operative cretinism*, that is, the development of the cretinoid state after the removal of the thyroid gland. Küster (quoted in the Report of the Committee on Myxœdema, Transactions of the Clinical Society, 1888, No. 21, Supplement) extirpated the thyroid gland in a fourteen-year-old boy. Thereafter, the lad's growth was arrested, so that he always retained the characteristics of a boy of that age. Kappeler (*ibid.*) performed total thyroidectomy in a boy twelve and a half years old, who afterward did not grow, and developed some of the symptoms of myxœdema. Intelligence, however, was preserved. Kocher (*ibid.*) removed the entire thyroid from a child aged six, with the result that the physical symptoms of cretinism developed, although the mental symptoms remained in abeyance. Costengo (*Riv. Ven. di Sc. med.*, vol. xx., No. 2) reports a case of total thyroidectomy in a boy. Nine years after the operation the patient was a complete cretin. In a case reported by Sulzer (*Deutsche Zeitschrift für Chir.*, 1893) a goitrous thyroid was removed from a boy twelve and a half years old. Within five years typical cretinism had developed. On the appearance of a new thyroid, the boy improved, and within four years had regained all that he had lost. It was found that a piece of the gland had been left behind, and that it did not begin to grow until eight years after the operation. Palleske (*Deutsche medicinische Wochenschrift*, 1895) removed the thyroid from a girl of thirteen, who three years afterward was a typical cretin. Other cases are reported by Grundler (*Beitr. zur klin. Chir.*, 1883, No. 1), Julliard, Lancereaux, and Dolega (cited by Hofmeister, *Beiträge zur klin. Chir.*, 1894). Schmid (*Berliner klin. Wochensch.*, 1886, p. 509) removed the thyroid gland *in toto* from a boy fourteen years old, who afterward developed typical cretinism. He had absolutely no memory, and did not grow after the operation. Brian and Sargnon (*Gaz. hebdom. de Méd. et de Chir.*, 1898) report the case of a man thirty years old, who was in a moderate cretinoid state, and had a

goitre. This was removed by operation; within one year later complete cretinism had developed.

3. *Animal Experiments.*—The removal of the thyroid gland in young, growing animals, if the animals survive any length of time, is generally productive of an arrest of growth, and a state comparable to cretinism in man (Hofmeister, *loc. cit.*). The majority of animals die if the whole gland is removed, whether it be done in one or in two operations. In some experiments made by W. S. Carter and myself, this was the invariable result. Eiselsberg, however ("Ueber Tetanus im Anschlusse an Kropfoperationen," 1890), found that if only four-fifths of the gland are removed, the animals survive, and subsequently develop a myxœdematous state. It must be admitted that not all experimenters have been able to produce the same results. Munk, for example (Sitzungsberichte der königl. preuss. Akademie der Wissensch., 1888, No. 40) was never able to produce myxœdema or cretinism in apes by thyroidectomy. The animals all died with tetanic symptoms. The most suggestive experiments are those made more recently by Eiselsberg (*Langenbeck's Archiv*, 1895, vol. xlix.). He removed the thyroid from two lambs when they were about a week old. At the end of six months they weighed 10 and 14 kgm., respectively, while the control animals weighed 35 kgm. The disturbances were general, and involved the brain functions as well as the skeleton. Similar results were obtained in four goats and in one pig. One goat, however, developed in a normal manner, probably owing to the possession of an accessory thyroid gland.

4. *Therapeutic Results.*—The use of thyroid-gland extract in the treatment of cretinism has brought about remarkable results. It is true that these have been more brilliant in the case of sporadic, than in that of endemic cretinism; but it has not been systematically tried in the latter, and there are other factors of influence in the development of the disease. The successes obtained are, however, a strong confirmation of the view that cretinism is consequent upon disturbance or absence of the thyroid function.

The relation between the thyroidal changes and the development of cretinism is not definitely understood. The subject involves a consideration of the physiologic function of the thyroid gland, and that is not in place here. Suffice it to say that in the opinion of most authorities the thyroid gland produces a substance that acts as an antidote or antitoxin to certain toxic products of daily metabolism. Where the neutralization occurs is a matter of doubt, some holding that it takes place in the thyroid gland, and others that it takes place in the blood. If the toxins are not antagonized, they remain in the body and exercise a deleterious influence, primarily upon the nervous system, but also on the skeleton and other connective tissues. If the individual is young, the result will be an arrest of both physical and psychical development.

Normally the antitoxic action of the thyroid gland begins to be exercised early in life—according to Kinnicut (*Medical Record*, 1893), between the sixth and the eighth months of fœtal life. Failure of development (aplasia), imperfect development (hypoplasia), and morbid conditions in later life (such as atrophy, fibroid change, calcareous infiltration, acute inflammation, and goitre in all its forms), are the pathologic conditions that rob the body of the benefits conferred by a functionating thyroid gland.

Relation to Myxœdema.—The studies of English physicians, particularly Ord, Horsley, and Murray, have conclusively demonstrated that there is an intimate relationship between cretinism and myxœdema. Etiologically, the two affections are identical, in that their basis is a morbid condition of the thyroid gland; symptomatically, they also have considerable in common. The differences which they present are due to the fact that cretinism begins in childhood, at a time when the growing system is most impressionable to deprivation of the thyroidal influence; while myxœdema is the same disease developing after the body has reached its growth. Thyroid treatment produces beneficial results in both.

If it be accepted then as proved, that cretinism is due to absence or disease of the thyroid body, the next question to arise is, "What influences bring about the morbid condition in the gland?" The cause of its absence, poor development, or goitrous state, in sporadic cretinism, we do not definitely know. A number of reasons have been assigned: consanguinity of the parents, conception during alcoholic intoxication, fright during pregnancy, tuberculosis, and a neurotic taint; but the frequency of these conditions compared with the rarity of cretinism indicates that they possess little real importance. A study of embryologic pathology may throw light upon the subject. In rare cases, as in the one reported by Shields (*New York Medical Journal*, 1898, vol. ii., p. 476), the disease has followed upon an acute thyroiditis, undoubtedly of infective origin.

In the case of endemic cretinism, our knowledge is less meagre, although still far from complete. The fact that endemic cretinism and endemic goitre are in a large measure coextensive in distribution suggests a relationship between the two. At present, this relationship is interpreted as being that of a common causation: goitre and cretinism, it is believed, are due to the same cause. This view dates back to the early part of the nineteenth century, and was advocated by Fodéré ("Traité du goître et du crétinisme, precédé d'un discours sur l'influence de l'air humide sur l'entendement humain," Paris, an. viii., 1800), Gross (*loc. cit.*), Baillarger and Krishaber ("Dictionnaire des Sciences médicales, 1re série," vol. xxiii.), and Virchow. The common cause, nearly all observers agree, is to be found in the drinking-water. Goitre and cretinism always grow less frequent in affected localities when the water supply is changed. Thus, Bircher states that 59 per cent. of the school children of Rapperswyl, in the Swiss Canton of Aarau, had goitre in 1885. The town then made a change in the water supply, obtaining it from beyond the Aar, from a goitre-free district; and the percentage fell rapidly to 44 per cent. in 1886, 25 per cent. in 1889, and about 11 per cent. in 1895. In contiguous communities, living under identical conditions with the exception of the water supply, goitre and cretinism may prevail in one and be absent in the other. Thus, the Bozel district in the Tarantaise had, in 1848, 1,742 inhabitants, of which 900 had goitre and 109 were cretins, and a number semicretins. The St. Bon district, which is only a short distance away, using a different water supply, had no goitre and no cretinism. Upon the advice of the Sardinian Commission, Bozel changed to the St. Bon water, with the result that in 1864 there were but 39 goitres and only 58 cretins.

An active discussion has been waged upon the question as to the constituent of the water bringing about goitre and cretinism. It is known that only water from the soil, not rain or snow water, produces these disorders. At first, certain minerals—for example, gypsum—derived from the particular geologic formation in which the goitre streams have their source, were believed to be the active agents; but the occurrence of endemic goitre in localities the waters of which have an entirely different mineralization, makes this view untenable. The favorable influence exercised by iodine upon goitre led to the theory that the waters of goitrous districts were deficient in this substance. Against this not unreasonable supposition is the fact that goitre may and does exist in valleys the streams of which are rich in iodine—as the valleys of the Po, Aosta, and Isère—and may be absent where the water is free from iodine.

From this dilemma an escape was found in the assumption that the efficient agent in goitrogenic waters was a *contagium vivum*. This hypothesis is now generally adopted, Ewald in particular having strongly defended it; but it is not new, and was long ago expressed by Alexander von Humboldt, Troxler, Virchow, and Hirsch —to be sure, in pre-bacteriologic language. Demme and Gross had assumed the existence of a miasm which arose in the vapors of the marshes. Baillarger and Krishaber (*loc. cit.*) had also come to the conclusion that the goitrogenic substance was organic, although they did not go so far as to make of it a living substance. The fact that the boiling of the water renders it innocuous is one of the strongest arguments in favor of the modern theory. What the substance is, still remains a mystery. It may be bacterial, although no definite organism has been isolated. Tavel (quoted by Kocher, *Deutsche Zeitschrift f. klin. Chir.*, 1892, vol. xxxiv., p. 556), in a beautiful, clear stream in a goitrous district, found thirty-three varieties of plant life, although he was not able to prove definitely that any one of them was the sought-for cause of goitre.

Whatever the cause may be, it is not long-lived in the body. Goitre increases only as long as the infected water is drunk, and it may even disappear if the individual afterward consumes a pure water. Immunity to goitre may exist in goitrous localities. According to Kocher, persons who pass the tenth year in such a locality without the development of goitre, will usually remain immune. Whatever the nature of the morbific agent, it seems to expend itself upon the thyroid gland; and in the end it is the disturbance in the function of that organ that brings about cretinism.

There are, however, certain predisposing causes:

1. *Locality.* Endemic goitre occurs especially in sheltered, damp, and imperfectly aired valleys.

2. *Geologic Formation.* Goitre and cretinism are most common in sections characterized by marine sedimentary rocks, particularly those of the Paleozoic Era (Devonian, Silurian, Carboniferous, and Dyas), the Triassic, and the Tertiary. McClelland, in his Himalayan studies, found goitre most common in places in which the soils were rich in lime and magnesia, there being one goitre in every thirty-three, and one cretin in every thirty-two persons.

3. *Social Condition.* Endemic cretinism prevails among people eking out a meagre existence under unfavorable conditions. The influence of such conditions has been proved indirectly by the lessening of goitre and cretinism as such communities become more affluent and more civilized, the water supply remaining unchanged. Wallmann (*Wiener med. Jahrb.*, 1863, vol. i., p. 120) also considered despotic government a factor in the production of cretinism. There was an opinion, found not uncommonly in older writings, that cretins were the relics of an ancient, inferior race of human beings—an hypothesis that has, of course, no proof whatever.

4. *Consanguinity.* Inbreeding and consanguineous marriages are an important factor in the perpetuation of cretinism.

5. *Heredity.* When the parents are goitrous, even if the thyroid disease is slight, the children are very apt to develop cretinism; and this is particularly true, as indicated in the preceding paragraph, if the parents are related.

The Sardinian Commission found that of 3,613 fathers of cretins, 962 had goitre, and 51 were cretins; and of 3,652 mothers, 1,281 were afflicted with goitre. But that heredity is not of controlling moment is proved by the fact that, given good surroundings, the descendants of goitrous parents may develop normally, although they do not always do so. Goitre does not, however, of necessity bring about endemic cretinism; for in Ontario goitre is, according to Osler, quite prevalent, but cretinism is unknown. Goitre also formerly prevailed in Pennsylvania and New York (Demme, Gross), but cretinism was rare or unknown. Regarding Canada, however, while endemic cretinism does not occur, sporadic cretinism is by no means uncommon; and Macphedran (*Canada Journal of Medicine and Surgery*, 1898, vol. iv., p. 275) was able to collect no less than seventeen cases.

General Features.

Nothing is more characteristic than the physiognomy of a typical cretin. There is, moreover, a remarkable uniformity in the appearance of all persons afflicted with this disease, so that the characteristic individuality of normal human beings is largely obliterated. To such an extent is this the case that older writers, as already mentioned, considered cretins to be the remains of a degenerate aboriginal race.

The typical cretin is short of stature—a stunted, dwarfish being, with a large head resting almost upon the shoulders or sinking forward upon the chest. As a rule, the hair is short, coarse, and abundant, though sometimes long and silken, and grows well down over the low forehead. The skin is pale, thick, dry, rough, at times scaly, and has a tendency to form thick folds or waddles. The face is stupid, expressionless, and repulsive. The eyes gaze vacantly, seldom fixing objects. The nose is short and thick, with a deep-lying root and flaring nostrils. The mouth is large; the lips are thick and fleshy, and constantly open, permitting the swollen tongue to protrude and the saliva to drool. The teeth are few in number, large, wide apart, and badly formed. The ears are fleshy, pale, often deformed, and usually stand out. Sometimes they are small and grown flat to the head. A short, thick neck, at times deformed by the presence of a goitre, joins the head to the thorax. The latter is disproportionately short, flattened irregularly at the level of the lower end of the sternum, and often scoliotic and kyphotic; it is usually smaller in circumference than is normal. The breasts in female cretins are either not developed at all, or are very large and pendulous. The abdomen is protuberant and inclined to hang downward; often a hernia, either umbilical or inguinal, is present. Lordosis is common. In both sexes the genitalia are usually small and infantile, with absence of hair in the pubic region, but in rare cases the external organs of generation are excessively developed. The extremities are short, fleshy, and grooved by deep furrows; the feet and hands are large; the nails roughened. Often there is a tendency to bow-leg or knock-knee. Many cretins cannot walk; some cannot even stand unless supported.

Intellectually, the cretin, as a rule, presents a degree of degeneracy that is on a par with that of his body. His wants are confined to the most rudimentary desires, such as hunger and thirst; and to these, even, he gives expression in ways that are intelligible only to those that are constantly about him. Speech he usually has not, and is able only to make monotonous, inarticulate noises, and does not employ gestures. If he speaks at all, his voice is shrill and unpleasant. He remains in all respects a helpless child, and often wears, even at two-score years or more, the garb of childhood.

In the foregoing I have given a brief sketch of the cretin in his worst estate—the type that Maffei calls plant-men (Pflanzenmenschen), on account of their purely vegetative existence. The picture is not overdrawn, and characterizes wellnigh the majority of cretins; but there are many in whom the disease does not reach such a profound degree, and in every locality in which the disease is endemic there are gradations, from the fully developed to the mild type—so mild, indeed, that only a few features of the disease remain. These slight cases are termed cretinoid.

Age.—Cretinism may be congenital; that is, it may be present at birth. In such cases the child rarely lives any length of time; indeed, it is often still-born. More frequently the disease develops some time after birth: in the endemic type, between the fifth and the eighth months; in the sporadic, after the second year, or later. The condition usually reaches its height at the age of fifteen years, and remains stationary after the twentieth year. According to Ord (Medico-Chirurgical Transactions, 1878), cretinism never develops in a child that is healthy up to its sixth or seventh year. Operative cretinism naturally begins after the operation, if that be done within the period of growth. The duration of life is generally short, especially in the sporadic form, in which the fourth decade is rarely attained. In endemic cretinism, subjects sometimes reach the exceptional age of seventy, or even one hundred years. Tuberculosis seems to be rare in cretins.

Sex.—Endemic cretinism is more common in the male sex. In sporadic cretinism there seems to be a decided preponderance of females. I have collected from the literature 93 cases of the sporadic type. The sex was mentioned in 86; of these, 48 occurred in females, 38 in males. Osler, in the American cases, only a few of which are included in my list, found the difference in favor of the female sex even greater; 35 females to 23 males.

FEATURES OF THE DISEASE IN DETAIL.

A. SOMATIC FEATURES.—1. *General Skeleton.*—The cretin is almost never of the normal stature of persons of his age; in the majority of cases indeed, his height does not exceed that of a child of three or four years. Maffei (quoted by Kocher, *loc. cit.*) found 22 out of 25 cretins to be less than 4.5 feet (140 cm.) in height; several were even less than 3 feet tall (95 cm.). Macphedran (*Canadian Journal of Medicine and Surgery*, 1898, vol. iv., p. 275) found the height in 9 cretins to vary from 26 to 55 inches. I have tabulated the heights of 28 cretins, ranging from four to fifty-three years of age, and found the average to be 96.6 cm. (38⅗ in.).

There is a disproportion among the different parts of the body. At times the arms are very long; the hands, large; the fingers, short; the nails, broad, flat, short, and brittle. The lower limbs are crooked, and there is often a backward extension of the knees. The clavicles are thin, delicate, and slightly curved. The hair is coarse, dry, and abundant; often reddish in the sporadic form, and chestnut-color in the endemic. There is usually no pubic or axillary hair, but sometimes a considerable hirsute growth is noted between the scapulæ. Fatty tumors are found above the clavicles, and occasionally between the shoulder-blades, but only in the sporadic, not in the endemic, type. Umbilical and inguinal hernias are common features. As already mentioned, the genitalia are small; but in some instances (Friedreich, "Ueber die äusseren Geschlechtsorgane der Kretinen in Iphofen," 1828) the male sexual organ reaches an enormous length, the testicles being in proportion, and usually very hard. Puberty, if it occurs at all, is late in appearance, sometimes, as in Wagner's observation (Medic.-chir. Centralblatt, 1893, 245), at the fortieth year. The cretin's skin is dry, harsh, and brownish or pale ashen in color. The veins of the chest are prominent, and there is often, as Bramwell ("Atlas of Clinical Medicine," vol. i., p. 16) has noted, a venous mottling of the legs. Eruptions are common in the sporadic form. The body temperature of cretins is nearly always subnormal.

The Head.—The head is unduly large, with a flat top and a prominent occiput. (Bulldog-like is the comparison made by some writers.) The circumference is, however, not so large as might be expected from the general appearance of the head, the average in twenty cases being 51 cm. (20⅗ in.); at times there is actual microcephaly. The fontanel and sutures remain open very long, although sometimes they close early. The shape of the head varies. It is usually brachycephalic in endemic cretinism and dolichocephalic in the sporadic type. The head is often so heavy that it cannot be held up by the weak neck muscles. The forehead is low, the supraorbital ridges are prominent, the eyebrows thin, the eyelashes short and few in number. The eyelids are swollen. The eyes are usually open, but sometimes half closed from ptosis. Many cretins have pronounced squint. Lachrymation is common, from occlusion of the lachrymal duct, and there is often well-marked epicanthus. The nose is retracted, short, and homely, with large, flaring nostrils. The upper jaw is usually unduly prominent, while the lower recedes. The lips are thick and fleshy (macrocheilia), and at times there is a pinkish flush upon the cheeks. The naso-labial folds are indistinct. The mouth is always open, and the breath offensive. There is constant drooling of saliva. The tongue is large, swollen, and in advanced cretinism protrudes from the mouth (macroglossia). The teeth appear late, and the milk teeth generally persist throughout life, second dentition being rare. The teeth are subject to early decay, and are always badly formed and of large size. The palatal arch is generally high and narrow. The neck is short. The thyroid gland as a rule cannot be felt in sporadic cretinism, and was absent at autopsy in nine out of ten cases collected by Bramwell (*loc. cit.*).

I have analyzed 88 cases of sporadic cretinism recorded in the literature with reference to the condition of the thyroid gland. There was no thyroid demonstrable in 44; there was no goitre, or the gland was normal in 9; goitre existed in 7; and no mention was made of the gland in 27. Osler, in his cases, a few of which are embodied in my table, found goitre present in 7, the gland normal in 12, and small in 2; it was not felt in 16, and not mentioned in 20. In one case of cretinism on which I had an opportunity to make the autopsy, the thyroid gland was absent. In endemic cretinism the thyroid is not only present, but is, as a rule, the seat of goitrous change. Wagner (*loc. cit.*) gives the frequency of goitre as high as ninety per cent.; others generally find a lower percentage. Among 20 cretins, Bircher found 15 with goitre, the thyroid not being palpable in one, and being normal in 4. Regarding the statement that the gland is normal, it must always be remembered that it is difficult to determine merely by palpation the condition of a thyroid gland. Cretinism is always worse in non-goitrous persons than in those having goitre.

Fleshy lipomatous masses are found above the clavicles and between the scapulæ, but only in sporadic cretinism. During wasting diseases and before death, these tumors generally atrophy.

Circulatory System and Blood.—The heart sounds are weak; the pulse is slow and feeble. The blood has not been carefully studied in endemic cretinism; and with regard to the sporadic form, the reports are also meagre. Koplik (New York *Medical Journal*, 1898, vol. ii., p. 84), in a female cretin one month of age, found the hæmoglobin ranging from 85 to 53 per cent.; the red blood corpuscles numbered 4,200,000, and the white cells, 10,000. In another case, an infant of nine weeks, presenting a typical cretinoid appearance, the hæmoglobin was 105 per cent., the red corpuscles numbered 3,000,000, and the white cells 13,500. After a short treatment with thyroid gland, the hæmoglobin sank to 55 per cent. In a case reported by Mendel (*Berliner klin. Wochenschrift*, 1896), the red cells were 4,700,000, the white cells 30,000, the differential count showing: polymorphonuclear cells, 58 per cent.; lymphocytes, 33 per cent.; eosinophiles, 5 per cent.; transitional forms, 4 per cent. Osler (*American Journal of the Medical Sciences*, 1893), in one case, found anæmia, leucocytosis, and poikilocytosis; and in another, absence of leucocytosis. Phillips (Transactions of the Clinical Society, 1885) reports finding in one case slight anæmia and no increase in the number of leucocytes. Garré (cited in *Virchow-Hirsch's Jahresbericht*, 1890, 341), in a female cretin of twelve years, found 3,900,000 red corpuscles, 5,730 white, and 63 per cent. hæmoglobin. In a female cretin twenty-six years old, Routh (Proceedings of the Medical Society of London, 1884, vol. vii., p. 309) found the red cells 86 per cent. of the normal; the hæmoglobin, 77 per cent.; and the relation of the white to the red cells as 1 to 250, showing a decided leucocytosis. From these blood studies, it is apparent that cretinism—at least, the sporadic form—is accompanied by anæmia, manifesting itself in a decided reduction of the red corpuscles and a diminution in the hæmoglobin; sometimes the red corpuscles present alterations in form. The leucocytes seem to be increased in the majority of cases, without any noteworthy alteration in the proportion of the different elements; in some instances, however, there is no leucocytosis. A thorough study of the blood—both of its cellular and of its liquid elements—is a distinct desideratum.

Digestive Tract.—The drooling of saliva and the thick, protuberant tongue have been mentioned. The appetite of the cretin is usually voracious, and he bolts his food. Constipation is generally present. In extreme types of the disease the bowels are moved involuntarily. In the terminal stages diarrhœa sets in, and may be the cause of death.

Genito-urinary Tract.—The sexual sense is usually absent. Puberty is rarely attained; and if so, not before the age of twenty-five, and sometimes as late as forty. Menstruation, if it occurs at all, is scanty and irregular. Cretins are generally sterile. The size of the external genitalia varies; as a rule, they are infantile; exceptionally, as already mentioned, very large. The urine is normal, but small in amount. In one case Ord (*Lancet*, 1893, vol. ii., p. 1113) estimated the quantity of urea, and found it to be 0.4 per cent. Urinary incontinence is the rule in typical cretins.

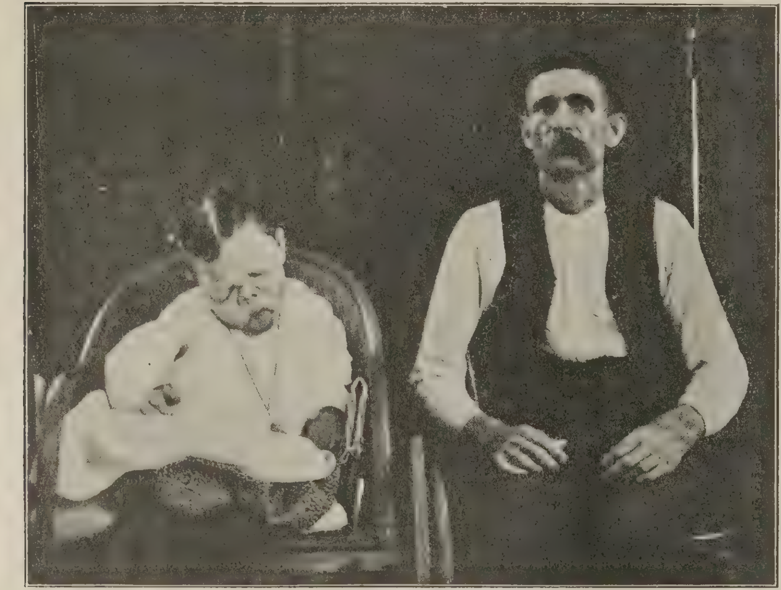

FIG. 2341.—Bartine Mills, a Cretin, about Thirty-three Years Old, formerly in the Philadelphia Hospital. The man beside him was his voluntary caretaker for many years.

B. MOTOR PHENOMENA.—On account of the short legs and large bodies, the gait of cretins is of a peculiar, grotesque, waddling character. Many can progress only by pushing a chair; some cannot even stand. The use of the hands for delicate movements is limited in varying degrees. Often the cretin cannot even feed himself. Regarding the reflexes, the statements in the literature differ considerably. Some have found the tendon reflexes normal; others, the knee jerks increased, and the abdominal, cremasteric, and other superficial reflexes, unaltered. Mayer (*Revue médicale de la Suisse romande*, 1883, 523) found a diminution in the faradic excitability of the muscles.

C. SENSORY PHENOMENA.—All the special senses are blunted, particularly that of hearing, complete deafness being a common feature. Some have attributed the low intelligence in part to this deafness. As to its cause, Wagner (*loc. cit.*) suggests that it is due to a myxœdematous swelling of the mucous membrane of the middle ear.

Hitchmann (*Wiener klin. Wochenschrift*, 1898, 655) has made a study of the eye conditions in 58 cretins. Lesions of that organ were, on the whole, rare. He found epicanthus in 12 and myxœdema of the lids in 56. Chronic catarrhal conjunctivitis was common, and was either an accidental condition, or due to disturbance of the tear duct. Eczema of the lids was frequent. Strabismus was found in but 1 case, senile cataract in 2, and posterior capsular cataract—due to prolapse of the retina—in 1. The retina was normal in 42. There was conus, with a downward axis, in 5 cases, which is a high percentage, as ordinarily this is found but 27 times in 1,000 cases. In one case there was beginning gray degeneration; and in 2, increased pigmentation of the choroid and retina. Nystagmus is sometimes present.

Touch, pain, and temperature sense, like the more highly specialized functions, are also greatly dulled.

D. PSYCHIC PHENOMENA.—I have already stated that cretinism presents all gradations from the most profound amentia and idiocy to mere feeble-mindedness, or even to a fair state of mentality. The majority of cretins are dull, apathetic, silent, unteachable, and incapable of work, and have to be cared for like infants. A few, particularly in endemic cretinism, are able to do light tasks, run errands, etc. Cretins, as a rule, are good-natured but jealous, and are not emotional; at times, however, they have violent outbursts of animal fury, or pass into states of deep depression. In rare instances, they present delusions or are maniacal; and Kraepelin refers to one case in which paresis existed. Convulsions have also been observed. In exceptional instances some one faculty will be extraordinarily developed, as, *e.g.*, the musical memory.

PATHOLOGICAL ANATOMY.—The general characters of the skin, hair, and nails have been described. A peculiar feature to which I might again allude is the gelatinous infiltration of the skin (cachexia pachydermica), which is particularly marked in sporadic cretinism. According to Beach, it is due to an excess of mucin in the subcutaneous tissue. In nearly all autopsies an absence of subcutaneous fat has been noticeable. Fatty tumors are found above the clavicles in sporadic cretinism.

With regard to the skeleton, I have already spoken of the shortening of the bones and the peculiar external features of the skull. The cause of the skeletal characteristics has been a subject of much dispute, but it is now proved that the fundamental defect is a delayed ossification of the cartilages. There is a retardation in the formation and growth of the centres of ossification, in the transformation of the epiphyses into bone, and in the disappearance of the epiphyseal discs. Eventually, if the individual lives long enough, ossification may be accomplished; but it is common to find, as did Dolega ("Beiträge zur pathol. Anatomie u. allgem. Pathologie," 1890, vol. ix., p. 488), in a cretin twenty-eight years of age, that the sutures remain open and that the epiphyses persist in their cartilaginous state. These facts also explain why cretins may continue to grow until the third or fourth decade of life.

Periosteal osteogenesis shows no constant characters; it may be normal, or it may be excessive. Sometimes there is a projection of the periosteum between the epiphysis and diaphysis, such as was observed in Dolega's case, but this is not the rule. Little is known of the condition of the bone marrow. In the only case in which it is mentioned—that of Langhans (*Virchow's Archiv*, 1892, 128)—the marrow was fatty. The case was that of a cretin fourteen months old.

In two fœtuses presenting cretinoid characteristics, Virchow ("Gesammelte Abhandlungen," 1856, 969; also in Verhand. d. phys.-med. Gesellschaft, Würzburg, 1856, 199) found synostosis of the spheno-occipital sutures—of the so-called os tribasilare—and concluded that this was an important feature in cretinism; one probably responsible for the arrest of growth in the other parts of the skeleton. Normally the sutures of the os tribasilare do not disappear until the twelfth or thirteenth year. There is, however, a general belief among authorities at the present day that the disease found in the fœtuses described by Virchow was not a form of cretinism, but a condition somewhat analogous, yet different in its essence, known as *chondrodystrophia fœtalis*, about which more will be said later. In true cretins there is no premature ossification of the sphenobasilar sutures.

The foramina for the cranial nerves and blood-vessels are often small, including the foramen magnum; sometimes, however, they—especially the latter—may be of normal size. Wormian bones are frequently present along the sutures.

In shape the skull, as has been stated, may be either dolichocephalic or brachycephalic. Shortening of its base is one of the most constant features of the cretinic skull. The root of the nose is depressed and prognathism is marked. Allen (New York *Medical Journal*, February 2d, 1895), in a supposedly cretinic skull, found projection of the occiput, and such a union of the parietals with that bone that a conspicuous depression was formed between them, giving rise to a shape of the head called "cat head."

Histologically the osseous changes are but little known. They can be satisfactorily studied only in juvenile cretins, and autopsies upon them are rare. Langhans (*loc. cit.*) found that in his case the cartilage cells were small and spindle-shaped; in places they were abnormally disposed, being longitudinal to the axis of the rows of cells. Sometimes, also, the rows were interrupted. The marrow spaces showed irregularities, being often very large and widely separated in the youngest portions of the bones, and exhibiting shortening of the bony trabeculæ.

The Brain.—An interesting pathological change is enlargement of the pituitary body, which, however, is not constant. It was noted by Boyce and Beadles (*Journal of Pathology and Bacteriology*, 1893) and by Packard and Hand (*American Journal of the Medical Sciences*, September, 1901). Langhans (*loc. cit.*) found the brain and cord normal, but in the peripheral nerves he observed dilatation of the lymph spaces of the endoneurium and perineurium. The dilated spaces, besides having fine fibrillæ, contained unilocular and multilocular vesicular cells, which seemed to have originated from the endoneurium. There were also peculiar cylindrical or spindle-shaped, solid structures, probably the result of degeneration of the connective tissue.

Thyroid Gland.—The condition of the thyroid gland, to which allusion has been made upon page 393, is of great interest. In sporadic cretinism it is usually absent; when present it is small and atrophic. In such cases the acini are smaller than normally, are devoid of colloid, and often are surrounded by thick bands of fibrous tissue. The blood-vessels, as in the case of Packard and Hand (*loc. cit.*), may show advanced calcareous infiltration of their walls. In endemic cretinism the gland is usually goitrous; sometimes, however, the thyroid is not demonstrable in the neck, but at autopsy a retrosternal goitre or one behind the sterno-cleido-mastoid muscle may be found.

The enlargement of the tongue is usually due to a lymphangiomatous condition of the organ. The viscera, in general, show no characteristic changes. Beach found an increase in the fibrous tissue; and in a case examined by myself the liver was the seat of an enormous number of cavernous angiomata and the hepatic cells were deeply pigmented.

Differential Diagnosis.—But little need be said regarding the differential diagnosis of cretinism. The endemic form usually presents no difficulties; and the sporadic in its fully developed state is also easily recognized. Occasionally it is necessary to distinguish between cretinism and *dwarfism* (nanosomia). In border-line cases the distinction may be impossible; but ordinarily we find that the dwarf does not present the typical skeletal changes nor the myxœdematous condition of the skin. There are likewise no real deformities: the large tongue is absent; and the psychic defects, so prominent in cretins, are not a feature of dwarfism. It may be difficult to distinguish between cretinism and that form of idiocy known as *Mongolian idiocy*. There are, however, mental differences that are of help in the diagnosis. The cretin is dull and apathetic; the Mongolian idiot, though stupid, has a smiling countenance, and is more or less vivacious and observant. The œdematous condition of the skin and the fatty tumors are also absent.

Under the term *infantilism*, several writers have described a condition of under-development, the individual retaining the characteristics of childhood at a period when these should have disappeared. The secondary sexual characters in particular fail to develop. Infantilism may be, and usually is, general, but according to Hertoghe ("Die Rolle der Schilddrüse bei Stillstand und Hemmung des Wachstums und der Entwicklung," from the French by Spiegelberg, Munich, 1900), it may affect single features, as the voice, the hair, the genitalia, etc. Brissaud considers infantilism an attenuated form of cretinism.

A few words must be bestowed upon the subject of so-called *fœtal rickets*, which by some is considered a form of fœtal cretinism. Few diseases are honored with so many high-sounding names as this. Besides being called fœtal rickets, it is known as cretinoid dysplasia, pseudorhachitism, chrondritis fœtalis, micromelia chondromalacica, achondroplasia, and chondrodystrophia fœtalis. Without going into the details of the affection, which are out of place in the present article, the following statements may be made:

1. The disease is not a form of rickets.

2. It has very little in common with cretinism, differing from the latter in certain essential points:

(*a*) In its period of development: it begins during fœtal life, and the child is generally still-born or dies early. Cretinism rarely begins before from the fifth to the eighth month.

(*b*) The thyroid gland is usually normal.

(*c*) It may occur anywhere, and is not more frequent in the foci of endemic cretinism than in other places.

(*d*) Although the osseous changes present no fundamental difference, there is in chondrodystrophia a sclerosis of the diaphysis which is absent in cretinism.

3. The essential feature of chondrodystrophia fœtalis is a disturbance in the development of the primordial cartilage, characterized by irregular growth of the cartilage cells with defective formation of the cellular rows. Regarding the cellular proliferation itself, it may be deficient, the cells being spindle-shaped in their hyaline matrix, or it may be excessive, or the cells may form groups lying in a soft, glassy matrix. These three types of abnormalities correspond with three types of the disease: chondrodystrophia hypoplastica, chondrodystrophia hyperplastica, and chondrodystrophia malacica.

4. Periosteal osteogenesis is not, as a rule, disturbed. Occasionally it is in excess of the normal.

5. An almost constant feature is the penetration of a periosteal process between the epiphysis and the diaphysis.

6. There is a sclerosis of the marrow, especially of the ends of the bones.

7. Ossification of the sutures of the os tribasilare is common, but not constant.

8. The dystrophy leads to a stunting of the growth, particularly of the lower limbs; hence the middle of the body is not at the umbilicus, but much higher—near the ensiform cartilage.

It is not impossible, however, that chondrodystrophia, although anatomically differing from cretinism, may like the latter be due to hypothyroidism.

Treatment.—The treatment of endemic cretinism is primarily a matter of broad public hygiene and sanitation. As the drinking-water is chiefly at fault, the first effort should be directed to its improvement. Whenever possible, water should be secured from a goitre-free district, the advantages accruing from such a change being truly remarkable. To one famous instance of the kind—that of Bozel—I have referred on page 391. When an entirely new water supply is unobtainable, an attempt should be made—of course, this is then not a matter for municipal performance, but of household initiative—to provide cistern water, which, it has been shown, is not goitrogenic, and, hence, not cretinogenic. Sedimentation of the water seems also to rob it, to a large extent, of its noxious properties; but boiling is the surest way to render it innocuous. In addition to giving attention to the water supply, amelioration of the general social conditions of the afflicted community must be sought, by preventing intermarriage, diversifying the industries, shortening the hours of work, improving the food supply, widening the streets, and modernizing the sewage system.

In sporadic cretinism remarkable results have been achieved by the so-called substitution treatment, *i.e.*, the substitution for the deficiency in the activity of the thyroid gland of either the gland itself, obtained from animals, or preparations made from it. It is unnecessary to dwell upon the development of this treatment, although it forms an interesting chapter in the history of medicine. The father of it, as at present practised, is G. R. Murray, of Newcastle-on-Tyne; although the value of the gland in the treatment of conditions dependent upon absence or disease of the thyroid body had previously been recognized both by Bircher and by Horsley. They, however, had recommended the implantation of the gland—a method not devoid of danger. At the present day numerous preparations of the thyroid are on the market. Some represent the gland in a dried state—the so-called desiccated thyroid; others are glycerin or ethereal extracts in liquid or solid form. As a rule, the gland from the sheep or the calf is employed, but that of the hog also seems to be efficacious. Attempts have been made to isolate the active principle and to use it instead of the extract or the gland itself. Different investigators, however, have isolated different substances, each claiming that his is the active principle; thus, there are Baumann's thyroiodin, Notkin's thyreoprotein, Fränkel's thyroantitoxin, and Hutchinson's colloid. The active principle seems to contain iodine.

The dose of thyroid is more or less arbitrary and varies with the preparation. It is well to begin with small doses (for example, a minim of the liquid or a grain (0.06 gram) of the solid extract nightly), increasing the dose with care. The younger the cretin, the more brilliant are the results; but there is no period, except, perhaps, extreme old age, at which it is not wise and proper to make a trial of the remedy.

Under the treatment a wonderful change comes over the entire system of the individual. There is a growth in height and a diminution in the general bulk of the body; a disappearance of the œdema of the skin, of the swelling of the tongue, and of the fatty tumors; a rise in body temperature; an improvement in the condition of the bowels; and a very striking increase in the intelligence. There is in the beginning, as pointed out by Thomson (*British Medical Jonrnal*, 1893, vol. ii., p. 677), a slight tendency to muscular debility, connected with the tremendous change in bodily metabolism; but this soon disappears.

If the thyroid medication is too active, symptoms of intoxication—so-called hyperthyroidism—may develop. These are tachycardia, pains in the limbs and elsewhere, slight fever, and diarrhœa.

Under thyroid treatment the diet should receive some attention. The use of meat should be restricted, and the food should be largely vegetarian in character.

A number of cretins that were under thyroid treatment have succumbed with astonishing rapidity to infectious diseases, such as diphtheria, typhoid fever, etc. Whether the thyroid medication had in any way lessened the patients' resistance to these is a fair question, but one which cannot as yet be definitely answered. The benefits obtained from the treatment so far outweigh any possible disadvantages that the latter need scarcely be given a thought.

In order that the beneficial effects of the thyroid treatment may not be lost, it is necessary to continue the administration of the drug throughout the patient's life. The lowest efficient dose should be determined, and then kept up uninterruptedly.

Specific medication with thyroid gland, which has been of such signal benefit in sporadic cretinism, has, so far, not met with striking success in the endemic form. The reasons for this are manifold. In the first place, the method has not been tried upon any large scale; secondly, the causes underlying the endemic cretinism continue; and thirdly, the majority of cretins were at a comparatively advanced age when the treatment was begun. It would seem advisable to administer the substance in a more or less routine way, as is done with quinine, for instance, in malarious districts, and thereby to aid the hygienic factors which have been mentioned. In any case the earliest manifestations of the cretinoid condition should be a spur to the use of thyroid preparations. Unfortunately, the state of civilization in cretin and goitre communities is, as a rule, so low that the people are slow to accept benefits, even if they do not actively resist them. To them applies the saying of Goethe: "Die Menschen wollen zu ihrem Glücke gezwungen sein."

I have referred to border-line cases that seem to bridge the chasm between idiocy and cretinism, and between dwarfism and cretinism. In them, as well as in infantilism, it is proper to make a test of thyroid treatment. A beneficial effect is proof that in the given case some of the elements of cretinism were present.

David Riesman.

GOITRE, EXOPHTHALMIC. See the APPENDIX.

GOITRE. (SURGICAL.)—In the treatment of goitre, surgical measures may become necessary, because internal medication has failed to stop the growth of the tumor or to relieve dyspnœa or other severe symptoms; or an operation may be resorted to, merely to free the patient from a disfiguring tumor.

External applications have little effect upon a goitre. The reports of success from the application of iodine in some form or other, or from the use of electricity, have been too few and too scattered to count for much.

Injection.—Many surgeons have reported excellent results from the treatment of goitre by injection, but on the other hand not a few deaths have been reported, so that one should be careful in advocating the use of injections. Since the perfection of the operative treatment, and the greatly diminished mortality of the operations performed for goitre in the last few years, the field for injection has been much limited. There will still be instances, no doubt, in which patients will absolutely refuse an operation, or in which on some other account a surgeon will be justified in injecting a goitre with iodine or iodoform; but such injection should be made with a clear understanding of its danger, and, it is hardly necessary to add, under strict aseptic precautions. Even then there is danger from hemorrhage and embolism.

Besides the tincture of iodine which has been most generally employed for injection, carbolic acid, alcohol, arsenic, and ergotin have been tried, but they are less effective than iodine, and do not decrease the danger of this method of treatment. Iodoform is the only substitute which has found many friends. It should be mixed with ether and olive oil in the proportions of 1 part of iodoform to 7 parts each of ether and oil. When the mixture turns brown it contains free iodine, and should be discarded.

To lessen the risk of hemorrhage, the hollow needle should be separately introduced. When it is seen that no blood escapes from it, the syringe should be attached, and ten or fifteen drops of the chosen mixture slowly injected. The resulting pain is sometimes very great, but lasts only for a few moments. The effect upon the gland is more or less marked according to circumstances. There may be an initial swelling, followed in a few days by more or less shrinking. Usually ten or twenty treatments will be required. These may occur at intervals of three days or more according to the amount of reaction. Parenchymatous goitre is best suited to treatment by injection, and this is the type of the disease which is most benefited by internal remedies. If the treatment is successful, there will in a few days be a distinct shrinking of the gland apparent to the eye and finger, and also capable of demonstration by measurements of the neck.

Operation.—Many operations have been advocated for the relief of goitre. Three of them have proved their worth and may be spoken of as classical. They are partial resection, enucleation, and ligation of the thyroid arteries.

Removal of the whole gland was formerly practised, but has been pretty nearly given up on account of the fact that acute or chronic "cachexia thyreopriva" follows in twenty-five per cent. of the cases. The acute form of this trouble is marked by tetanic symptoms which may terminate in speedy death. In the more chronic form surgical myxœdema develops, and this too may increase in severity till the patient succumbs. Hence total thyroidectomy, except for malignant disease, may be considered an unjustifiable operation. Partial resection is rarely followed by symptoms of tetanus, and when they do occur they are light and usually transitory.

Before any operation is performed upon a goitre, the patient should be prepared with all possible care. The difficulty of carrying out perfect asepsis so near to the mouth, the proximity of the tumor to important vessels and nerves, and above all the risk of sudden and severe hemorrhage, make the operations upon the gland much more serious than they appear at first sight to be. True, the mortality is small when a single surgeon operates upon a long series of patients, Kocher, for example, having reported a mortality of much less than one per cent.; but under ordinary circumstances a mortality of five per cent. may be expected.

Choice of an Anæsthetic.—Some surgeons advocate the use of ether, some of chloroform, and some prefer to use cocaine or some other local anæsthetic. The last plan possesses one advantage, namely, that the patient by speaking can demonstrate that the recurrent laryngeal nerve is not injured. A local anæsthetic should be chosen in cases of goitre accompanied by severe dyspnœa.

Incision.—A transverse incision is now generally preferred, as it well exposes the tumor, and leaves a scar in the direction of the wrinkles of the neck, and therefore not a conspicuous one. In case of a very large or deep-seated swelling, Kocher employs an angular incision, extending transversely on the level of the thyroid cartilage, from the sterno-mastoid muscle to the median line, and then bending downward to the sternum if necessary. This incision avoids the complete division of the sterno-laryngeal muscles.

Partial Resection.—When the skin incision has been made, and all superficial veins have been divided between ligatures, the muscles which lie in the way must be divided or drawn to one side, and the superficial fascia which overlies the true capsule of the gland must be divided and retracted. Beginning then with the upper and lower poles of the gland the surgeon carefully separates it from the surrounding tissues, placing ligatures around arteries and veins, and gradually dislocating the gland—as fast as it is freed—toward the median line. It is very important that every vessel should be clearly seen before it is clamped or ligated. If this rule is followed, the recurrent laryngeal nerve, which is closely associated with the inferior thyroid artery, will not be injured. Sudden hemorrhage should be controlled by compression, not by hasty clamping. The gland is often intimately attached to the trachea, and it is therefore better to leave a small portion of it behind, rather than to risk injury to the nerve by too violent attempts at removal. Hemorrhage from the substance of the gland, either where the isthmus is divided or elsewhere, may be controlled by cauterization or by ligature. The divided muscles are to be sutured. If the wound is deep, it should be drained for a couple of days.

The amount of gland tissue to be left depends a good deal on the shape of the goitre. If only one side of the gland is affected, the other is naturally left. If both sides require removal, enough gland tissue should be left to equal in bulk at least one-fifth of a normal gland. This tissue should be left at the poles of the gland, preferably about the inferior thyroid arteries, so as to reduce the risk of injuring the recurrent laryngeals.

Enucleation.—If a goitre is due to the development of distinct nodules within the thyroid gland, these may be enucleated. The ease with which this procedure may be carried out depends largely on how free these nodules are. Sometimes they may be shelled out from the surrounding gland tissue, almost as readily as non-inflamed tuberculous glands from their fibrous coverings. At other times the enucleation, on account of close attachment of the nodules, becomes virtually a partial resection. In such cases bleeding may be very troublesome, while on account of the depth of the holes which remain infection is more likely to follow in any case of enucleation than in a partial resection. Moreover, recurrence of the goitre is said to be more frequent after enucleation than after partial resection. Previous treatment by injection makes enucleation very difficult. There is little danger of injury to the nerves or jugular veins during enucleation. The skin incision is the same as that for partial resection.

Ligation of the Thyroid Arteries.—By the ligation of the thyroid arteries a certain amount of atrophy of a goitre may be accomplished. The superior artery is easily found through an incision along the median border of the sterno-mastoid muscle. The inferior may also be reached through this incision; but an easier method is to make a transverse incision situated far enough backward to allow the sterno-mastoid muscle to be drawn forward out of the way. The thyroid axis can be reached in this manner, and the inferior thyroid separated and tied near its origin.

Exothyropexy.—Jaboulay and a few other surgeons have succeeded in bringing about atrophy of a goitre by dissecting the enlarged gland sufficiently free to allow it to be brought into the wound, there to remain until healing by granulation shall have taken place—*i.e.*, for from three to eight weeks. Of the first sixty-five patients so operated upon four died, so that the operation is not without danger, and on account of its other obvious disadvantages it has not been generally taken up.

The two operations, therefore, which are most valuable are enucleation and partial resection; the former for isolated cysts and solid tumors, and the latter for diffuse and adherent goitres and all rapidly growing ones, since it best provides against recurrence.

Edward Milton Foote.

GOLD.—So far as determined, the action of gold upon the animal system resembles that of mercury more nearly than that of any other of the well-known heavy metals. Locally, soluble gold salts are powerfully irritant, and, constitutionally, gold compounds affect nutrition. In therapeutic doses they tend, like mercurials, to improve nutritive tone, but in poisonous quantities to derange it, with the development of stomatitis and gastro-enteritis, and, in continued dosage, of emaciation and progressive general enfeeblement. Gold has the common reputation of being a nerve tonic, especially in cases of nervous derangement in the genital apparatus, particularly the ovaries. Therapeutically, it has been used in ovarian inflammation and irritation, in amenorrhœa, in loss of virility, and in various conditions of impaired nerve power, and also as a substitute for, or adjuvant of, mercury in the treatment of constitutional syphilis.

In none of these applications can gold be considered a medicine of first-rate, nor possibly even of second-rate power. The sole compound of gold official in the United States Pharmacopœia is that entitled *Auri et Sodii Chloridum*, Gold and Sodium Chloride. This is "a mixture of equal parts, by weight, of dry gold chloride and sodium chloride" (U. S. P.). The compound is easily obtained by mixing in proper proportion solutions of the two salts and evaporating to dryness. It crystallizes in elongated prisms, but is commonly found as "an orange-yellow powder, odorless, having a saline and metallic taste, and slightly deliquescent in damp air" (U. S. P.). The compound is freely soluble in water, and the solution has a slightly acid reaction. This preparation is locally irritant even to causticity, and constitutionally exerts the virtues of gold as already set forth. The dose is about 0.005 gm. (about gr. $\frac{1}{12}$) three times a day, in lozenge or pill.

Edward Curtis.

GOLDTHREAD.—Coptis. The rhizome of *Coptis trifolia* (L.) Salisb. (fam. *Ranunculaceæ*). This plant is a pretty little evergreen bog-plant, with long, bright-yellow, thread-like rhizomes; bright-green and shining ternate leaves, and white, solitary, star-shaped flowers. It grows rather abundantly in the cold bogs of America, Europe, and Asia. The whole plant is generally collected, although the rhizome is undoubtedly the most efficient part. The description of the plant given above is sufficient for the drug, which has an intensely bitter taste, but no odor. The color, taste, and medicinal value of goldthread are due to a salt of the alkaloid *berberine*, which it contains in considerable quantity. A second alkaloid, *coptine*, is described by Gross as also present, but does not affect the medical properties of the former.

Goldthread is a simple bitter. It is frequently used in the country as a mouth wash for aphthous and herpetic ulcerations, etc. The ordinary dose is 1 to 4 gm. (gr. xv.–lx.).

The root of *Coptis Teeta* Wallich, of Asia, is a classic remedy for sore eyes, and still used in the Orient. Its properties are similar to those of goldthread.

W. P. Bolles.

GONORRHŒA.—Gonorrhœa, blennorrhœa, or clap is a contagious, inflammatory disease of the urethral mucous membrane, of venereal origin, and having as its cause a well-identified micro-organism, the gonococcus of Neisser.

This micro-organism was first isolated by Albert Neisser, in 1879, and has since been indubitably demonstrated to be the pathological principle of gonorrhœa.

It is a somewhat oval micrococcus, usually taking the diplococcic form, the individual coccus not being spherical but flattened on the side toward its neighbor, appearing more like a discoid formation than a true sphere; the individual cocci having, according to Haab, a diameter of 0.4 to 0.6 μ. They form in clusters, never in chains, this being due to the method of division; as a separation in one diameter is followed by the next in a direction perpendicular to the first. In this manner are formed groups or clusters of four, eight, sixteen, etc., and not long chains increasing in length by fission in the same direction. They are usually attached to epithelial cells and pus corpuscles, and are found free in the fluid only when present in great numbers. The gonococcus may be cultivated, probably the best medium for this purpose being hydrocele or chest serum in neutral agar in the proportion of one to three. The medium should always be alkaline in reaction, and kept at a temperature of about 36° C.

The period of incubation of a gonorrhœa, *i.e.*, from the time of inoculation to the appearance of the first symptoms, varies from three to seven days; and though occasionally a somewhat longer period elapses, an incubation extending over more than fourteen days is extremely rare, if it ever occurs.

The attention of the patient is usually first attracted by a slight pricking or itching of the meatus, and on examination he finds the orifice somewhat reddened, the lips may be stuck together, and a drop of viscid or semipurulent fluid squeezed out. The discharge rapidly increases and becomes purulent, and the act of urination gives rise to a certain amount of smarting. At the end of the first or beginning of the second week this discharge appears as a thick, green pus, which flows copiously from the meatus night and day, and so freely as to soil the clothing and genitals of the patient, the color of the discharge changing to a bright yellow on drying. Other symptoms of the inflammatory condition also appear. The meatus and surrounding parts are swollen, and the entire urethra in the pendulous portion is tender on pressure, and may be felt from the outside to be thickened and indurated. Sharp pains occur spontaneously, and are especially severe during erections. These latter are more frequent during the early morning hours in bed, and are extremely distressing to the patient, the penis being curved downward, owing to the diminished elasticity of the urethra (chordee). The urethral mucous membrane is swollen and the stream of urine small and split up. The passage of urine is extremely painful, causing an intense burning along the urethra.

This aggravation of the symptoms usually continues into the third week, the inflammatory process having by this time extended to the bulb of the urethra. In addition to the other symptoms a feeling of weight, heat, and fulness is felt in the perineum. During this inflammatory period the patient also experiences a feeling of general malaise with slight feverishness, which, together with the mental distress, causes him to be greatly depressed.

About the end of the third week, in typical cases of acute anterior gonorrhœa, a rapid improvement occurs. The inflammatory and subjective symptoms diminish; the secretion, though still profuse, becomes thinner, later diminishes in amount, and finally is present only as a small drop in the morning on rising, disappearing entirely about the sixth or seventh week after infection.

While this description may be considered fairly typical, by far the greater number of cases do not end so happily. The inflammatory process overcoming the resistance of the compressor urethræ muscle invades the deeper urethra, and a new set of symptoms develop, while the difficulty of effecting a cure is increased. Owing to the close anatomical relation with the prostate, seminal vesicles, and epididymides, the disease is apt to involve any of these organs and disagreeable complications ensue. At times the invasion of the posterior urethra is acute, and is announced by the desire to urinate frequently and with extreme urgency, which may become exceedingly distressing to the patient. The tenesmus may be almost constant and is not relieved by urination; while a few drops of blood may appear at the end of urination, which always alarms the patient but is of no serious importance. In subacute cases this tenesmus is less constant, being present only when there is a certain amount of urine in the bladder; the patient will experience a sudden desire to urinate and is often unable to avoid wetting his clothing At this time smarting or burning sensations, or lancinating pains, are experienced in the deep urethra, and they are increased by the acts of defecation and micturition. Nocturnal emissions are apt to be frequent, and are accompanied by pain in the deep urethra. These are due to the inflammatory condition of the caput gallinaginis, and are almost positive evidence that the deep urethra has become involved.

The secretion is similar to that of anterior urethritis (muco-purulent). The patient is usually much depressed, complexion sallow, a slight amount of fever is present, and there is loss of appetite with obstinate constipation.

In some cases, however, all these symptoms may be greatly intensified. Not only may the prepuce become œdematous but also the entire body of the penis may undergo enlargement through lymphangitis. At the same time there is likely to be an extremely abundant secretion, sometimes mixed with blood and containing large numbers of gonococci, which are also found in the free fluid. Extreme sexual irritation and chordee are present, and there is fever due to implication of the general system.

On the other hand, the infection may be subacute from the start. The period of incubation and the stage of prodromes last longer, the inflammation is less intense, and general symptoms may be entirely absent. While the secretion always contains pus, it is more gelatinous and does not become more than muco-purulent in these cases. Gonococci are present usually in the flat epithelial cells. This condition is extremely insidious and is almost certain to involve the posterior urethra, causing chronic posterior urethritis and prostatitis.

Diagnosis.—The history of a definite exposure, a period of incubation, together with the subjective symptoms, render the diagnosis of a gonorrhœal urethritis comparatively easy. At the same time there exist several forms of urethral inflammation which closely resemble it, particularly at the outset; so that it becomes exceedingly important, as regards both the prognosis and the treatment, to determine definitely the true character of the disease as early as possible. The true nature of the disease can be determined by the presence or absence of the gonococcus in the secretions, by means of the microscope.

An examination of a fresh specimen of gonorrhœal pus, under a high-power oil-immersion lens, will demonstrate the presence of gonococci in some of the pus and epithelial cells in the form of small clusters of minute refractive bodies having movements of oscillation and rotation; but in order to examine these satisfactorily the use of some staining agent becomes necessary. Fortunately, the gonococcus has a well-marked affinity for all of the basic aniline dyes, and is very easily stained with simple solutions of fuchsin, methyl violet, gentian violet, or methyl blue.

A good working method is to place a small drop of the suspected pus on a clean microscopic slide, and with another slide spread this out into a thin film as evenly as possible. This is allowed to dry thoroughly, and is then covered with a strong solution of any basic aniline color which is allowed to remain for about one minute, when it is washed off with cold water and a thin cover-glass placed over the stained specimen, which can be immediately examined under the microscope, or may be mounted in Canada balsam as a permanent specimen.

The microscope should be provided with a high-power lens (one-twelfth oil immersion) and the Abbe condenser.

A method of double staining is recommended by Weiss; this is sometimes useful, as it colors the microbes in a different manner from the neighboring tissues. A saturated solution of fuchsin and thionin and a two-per-cent. solution of carbolic acid in water are mixed in the proportion of one to four. The specimen is stained with this for half a minute and then rinsed with water. The gonococci appear blue, the protoplasm of the pus cells red, the nuclei bluish-red, the epithelia deep red, and their nuclei reddish-blue.

As the gonococcus is closely simulated by several other micro-organisms, it is sometimes necessary to differentiate it from these. Perhaps the easiest way of accomplishing this is by means of the staining method of Gram, which depends on the fact that gonococci do not stain with iodine. Heiman gives the following method of making the Gram test: "To 10 c.c. of water add 2 c.c. of aniline oil, shake well, and filter through moist filter paper. To the clear aniline water obtained add 1 c.c. of ninety-seven-per-cent. alcohol and 1 c.c. of a concentrated alcoholic gentian-violet solution. This is about the quantity required for ordinary staining. After passing the cover-glass quickly through the flame, it is then placed in this solution for from two to three minutes. Gram next states that the cover-glass may be washed in alcohol or not, as preferred. I prefer to drain off the excess on filter paper without washing in alcohol. The cover-glass is then placed for five minutes in Gram's solution of iodine, which consists of iodine, 1 part; iodide of potassium, 2 parts; water, 300 parts; immediately afterward it is to be placed in alcohol (97 per cent.) in order to wash out all the coloring matter. It is sometimes advisable to renew the alcohol.

"Now wash the cover-glass well with water and place it in a Bismarck brown solution 1 part, water 5 parts, for one or two minutes, then wash in water and mount in balsam."

The difficulty in regard to this method of differentiation is that it furnishes only proof of a negative character; as by its use the gonococci disappear from the field, while other forms of bacteria resembling them are stained by the iodine and remain.

Prognosis.—The idea so prevalent among the laity, and also unfortunately among a large number of the medical profession, that gonorrhœa is a comparatively unimportant disease and unworthy of very serious consideration, is erroneous in the extreme and cannot be too vigorously combated. For although it rarely results fatally in itself, its complications not infrequently end in sterility, the loss of an important joint, permanent damage to the kidney, or even death itself.

The fact also that the germ may linger for years in the urethra of the unsuspecting victim, eventually to contaminate an innocent wife, bringing in its train those terrible ovarian difficulties which it is so capable of producing, is alone sufficient to class it among the most serious maladies of the human race.

In regard to the duration of the discharge, it is impossible to give a definite prognosis; though it may be said that an individual who recovers in from four to six weeks may be considered exceedingly fortunate.

Treatment.—The discovery of the gonococcus as the etiological factor in gonorrhœa has naturally revolutionized the treatment of the disease, although many of the old remedies which had formerly been used purely empirically possess a bactericidal action and are useful in the modern methods of treatment.

To begin with, the diagnosis of a true gonorrhœa having been made, the patient should be instructed to avoid all factors which affect the disease unfavorably; and he should also be advised in regard to his manner of living during the attack. Most important is it that he should be informed of the contagious properties of the discharge, and of the danger of infecting either his own eyes or the eyes of those with whom he may be brought into familiar contact. This is a very real danger, particularly as patients are apt to grow careless as the disease progresses; indeed, not infrequently both eyes become involved, and sometimes the final result is a total loss of sight. The discharge, usually profuse, should be received on a pledget of absorbent cotton, which may be tucked into the prepuce, or placed in a small bag, which is tied over the penis behind the corona glandis. Many drug stores sell a contrivance known as the gonorrhœal apron, which consists of a small bag about six inches long by four wide, which is fastened about the waist by tapes, and the penis is introduced into it through a hole on the side next to the body. This is filled with absorbent cotton, which is removed and destroyed from time to time as it becomes soiled. A buttoned flap on the front side of the bag allows the penis to be freed for purposes of urination. The soiled cotton should be burned and the hands thoroughly washed with soap and water after touching the penis or soiled cotton.

The most favorable condition for a patient during the acute period is that afforded by rest in bed; but unfortunately this will rarely be submitted to. A patient who could readily be induced to remain in bed with a simple sore throat will stubbornly resist such a course in case of a gonorrhœa which causes him far more inconvenience; he feels that by remaining about he avoids the suspicion of his friends. At all events, all forms of violent exercise should be avoided, as also should sexual excitement, which exerts a most pernicious effect. The swelling and inflammatory condition of the penis may be somewhat obviated by soaking the penis in water as hot as the patient can bear, a procedure which will also relieve the dysuria, the urine being passed while the penis is still immersed. This dysuria, which at times is very distressing, is caused by the dilatation of the inflamed urethra by the stream of urine, and also by the acid character of the urine itself, which acidity should be overcome by drinking copiously of water, or still lithia waters, or of strong lemonade. The addition of citrate of potassium to the water is also beneficial. ℞ Potassii citratis, ℥ i.; aquæ destil., ℥ iv. M. et Sig.: A teaspoonful in a full glass of water four times a day.

If the dysuria be very severe, a drachm of a two-per-cent. solution of cocaine may be injected into the urethra, rubbing it backward to the deeper urethra with the finger underneath the penis, a few minutes before urinating.

In regard to the diet of the patient, it should be simple and easily digested; he should avoid hearty and rich foods, and especially asparagus, tomatoes, and rhubarb. Alcohol should be entirely interdicted in any form, and this prohibition should likewise extend to carbonated waters, ginger ale, and the like.

Smoking in moderation is not injurious.

It is especially important that the bowels should be kept open, and a laxative dose of some of the saline aperients every morning before breakfast is usually beneficial.

In weak and run-down individuals a tonic may be of service; and in such cases the diet should not be reduced.

Internal Remedies.—The employment of internal remedies in the treatment of gonorrhœal urethritis with any idea of affecting the course of the disease is worse than useless; they are frequently productive of digestive disorders which are as serious as is the disease for which they are administered. Among such remedies may be mentioned cubebs, copaiba, sandal-wood oil, oil of turpentine, etc., drugs which have been handed down by an effete empiricism, and the administration of which may be followed by a complete anorexia, vomiting, diarrhœa, cutaneous erythemata, and chronic gastritis. As gonorrhœa is a local process we cannot expect, except in a very roundabout way, to influence its cure by the use of internal remedies. At the same time, certain urinary antiseptics are beneficial in preventing the decomposition of the urine, and also, by rendering the urine antiseptic, they may prevent the extension of the disease backward into the posterior urethra, and they certainly tend to prevent the occurrence of an ascending pyelo-nephritis. Among these drugs may be classed the salicylates, salol, salicylate of soda, etc., likewise methyl blue; and, above all, urotropin, by far the most valuable urinary antiseptic which we at present possess. The dose of this latter drug is from five to ten grains four times a day. This acts by liberating formaldehyde in the urine, and is of great value in all suppurative diseases of the genito-urinary tract.

Local Treatment.—As gonorrhœa is caused by a microorganism which exerts its influence upon a localized portion of the body and cannot in any sense be considered a general disease, local treatment would appear to be the most rational method of dealing with it, and as a matter of fact it has given by far the best clinical results.

One of the oldest and best-known forms of applying this local treatment is by means of urethral injections, and it is the plan which is most frequently chosen, being especially advantageous, as it can be used by the patient himself. The method of using injections is by means of a piston urethral syringe, which should be made of either hard rubber or glass, with a well-fitting piston, a conical point, and a capacity of from two to three drachms.

In administering these injections upon his own person the patient should first fill the syringe by immersing the point in the fluid and drawing up the piston, all the air being excluded by holding the syringe with the point upward and gently pressing upon the piston until the fluid oozes out. The penis should be held in the left hand with the glans between the forefinger and the thumb, which support it from beneath so that when they are brought together the meatus is compressed and the injected fluid is held in the urethra as long as is desired, after the removal of the syringe. The syringe should be held between the thumb and middle finger of the right hand, while the forefinger manipulates the piston. The conical point is inserted into the meatus and wedged sufficiently firmly to prevent the escape of fluid alongside the syringe, the piston being pressed steadily home until the urethra is fully distended. The thumb and finger of the left hand then compress the meatus, retaining the fluid in the urethra.

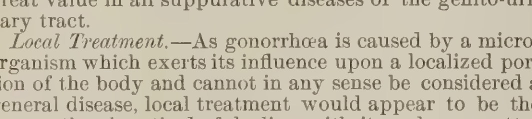

FIG. 2342.—Piston Urethral Syringe.

The patient should always urinate just before injecting, to prevent the discharge being washed backward by the injection as well as to present a clean surface for the medicated fluid to act upon.

The necessary essentials of a remedial solution suitable for use in such injections are that it should contain some antiseptic capable of destroying the gonococcus, but not of sufficient strength to injure the mucous membrane. It should be composed of ingredients which are completely soluble and should not be a mixture containing powders which may clog up the ducts of the urethral glands and so cause the formation of small follicular abscesses. It is desirable that the fluid injected should also have an astringent action and should not be of sufficient strength to cause the patient undue suffering.

In acute inflammations only very mild antiseptic injections should be used, but they should be administered more frequently than is necessary after the discharge has become chronic.

As every known substance has been used at one time or another as the basis of an infallible urethral injection, it is possible here to indicate only a few of the medicaments which have proved serviceable in my hands:

Potassium permanganate in aqueous solution varying in strength from 1 to 4,000 to 1 to 1,000; nitrate of silver of the same strength; the bichloride of mercury, 1 to 30,000, and, finally, the dioxide of hydrogen, 1 to 4.

Comparatively recently a new set of silver salts have been produced which have proved exceedingly valuable, possessing a marked bactericidal action and good penetrating power, and at the same time causing less pain than the silver nitrate. These are: protargol in watery solution of 0.5 to 2 per cent.; albargin, .05 to 0.2 per cent; argentamin, argonin, icthargol, and others which have given exceedingly good results.

In the latter stages of the disease when the discharge has become watery and the gonococci have disappeared, injections of a purely astringent character may prove of service. The sulphates or acetates of lead, zinc, or aluminum, or the vegetable astringents, hydrastis, krameria, rose-water, etc., may be used alone or in combination. The injection Brou, which has acquired a wide reputation among the laity, will serve as a type of this class of injection; it has the following composition:

℞ Zinci sulphat........................ gr. xv.
Plumbi acetat........................ gr. xxx.
Ext. krameriæ fluidæ,
Tinct. opii.................... āā ʒ iij.
Aquæ.................... q.s. ad ℥ vi.
M.

Abortive Injections. In attempts to abort a gonorrhœa at the very outset of the disease, exceedingly strong injections are sometimes used, as silver nitrate gr. xx.–xl. to the ounce. As a rule, if not always, these prove inefficacious; they are exceedingly painful, and are not to be recommended.

When the patient can come to the surgeon at least once a day, the continuous irrigation of the urethra with large quantities of fluid has proved a very successful method of treatment. An irrigator containing from two to four quarts of medicated solution is hung at an elevation; from this leads a rubber tubing, at the end of which is a glass or hard-rubber urethral nozzle. The patient stands up close to the edge of a sink or sits on the edge of a chair with a basin in front of him. The nozzle is pressed into the meatus, and the fluid turned on gradually until the urethra is filled, when a portion of the fluid is allowed to escape by the side of the nozzle, and circulation through the urethra is kept up in this way until the irrigator is emptied. A good form of nozzle for this purpose is known as Kiefer's, and consists of two hard-rubber tubes which come together in a conical point so that when the nozzle is held firmly in the meatus and the urethra is filled, fluid running through one of the tubes will flow out of the other. It must be remembered that the fluid will take the shortest way out, so that after the urethra has been distended with fluid, although the fluid continues to run from the outlet tube, the instrument fails to wash out the urethra unless it is so manipulated that the outlet is occasionally stopped with the finger which allows the urethra to balloon up; then the finger is removed and the fluid again permitted to run from the outlet tube.

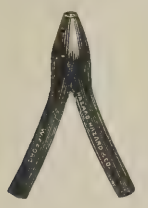
Fig. 2343.—The Kiefer Nozzle.

This tube can also be used to advantage in irrigations in which the bladder is filled without the use of the catheter. The finger being held steadily on the outlet tube, and the patient being requested to relax the sphincter muscles, the fluid will in most instances readily flow back into the bladder. This procedure should not be insisted upon too strongly. If the sphincter resists very forcibly, too much pressure should not be used, but frequently after one or two trials the surgeon will experience no difficulty in filling the bladder with ease in this manner in patients in whom at first it was found impossible to wash out the bladder in this way. The solutions used in this procedure are similar to those used in urethral injections, viz., the permanganate of potassium (from 1 to 6,000 to 1 to 1,000), nitrate of silver, bichloride of mercury, protargol, etc.

Posterior Urethritis.—While this has been considered one of the complications of gonorrhœa, it occurs so frequently that it may be said practically to constitute a constant symptom of the disease. At about the end of the third week the patient experiences a sense of heat and heaviness in the perineal region with an increase in the frequency of urination; it may be necessary to urinate every few minutes, and the act is often associated with considerable pain and occasionally with the passage of a few drops of blood. There is usually considerable urgency, the patient having to urinate instantly when the desire seizes him, without previous warning. Erections and painful nocturnal emissions are apt to occur; they are caused by the irritation of the inflammatory process.

On the other hand, the invasion of the posterior urethra may be exceedingly insidious and give almost no symptoms of its occurrence. In some cases a rectal examination will show a tenderness over the posterior urethra without prostatic enlargement.

To ascertain definitely whether the posterior urethra has become involved, perhaps the best method is one devised by Sir Henry Thompson, and known as the "two-glass test." In this test the first portion of the urine is passed into a clean glass, and the second into another. The compressor urethræ muscle being stronger than the internal sphincter of the bladder, the pus resulting from a suppurative inflammation in the posterior urethra, which lies between the two, is unable to overcome the firm resistance of the compressor, and therefore flows backward into the bladder and contaminates the urine within it, so that if anterior urethritis alone exists, the first portion of the urine will be cloudy, owing to the fact that it contains the washings of the anterior urethra, whereas the second portion will be clear, the first portion having washed the urethra clean. In posterior urethritis, however, both portions of the urine will be cloudy, because the pus formed in the posterior urethra has flowed back into the bladder and clouded the urine contained in it. Unless suppuration of the bladder or kidneys exists, this test is entirely satisfactory.

When posterior urethritis develops the irrigations should be allowed to go back into the bladder. The intense pain and frequency of urination may be controlled by suppositories of opium, and by an occasional local application of the nitrate of silver. A few drops of a solution of from five to ten grains to the ounce being introduced by means of Ultzmann's syringe, will be found exceedingly useful in stopping the tenesmus, or a two-per-cent. solution of protargol may be introduced in the same manner. To control the temporary increase in the tenesmus an injection of ten minims of a four-per cent. cocaine solution will often be found very effective.

Complications.—As the urethra is in close proximity to various organs, complications occur with a greater or less degree of frequency, and are often much more important and serious in their results than the original inflammation. Lack of space, however, prevents more than a casual mention of these.

Balanitis is an inflammatory condition of the mucous membrane of the glans penis which is apt to occur when the discharge is profuse. The patient should wash the penis three or four times daily with warm water and castile soap, drawing back the prepuce, and he should also allow the organ to soak for some time in an antiseptic solution.

Phimosis, a condition in which the preputial orifice is too small to allow the retraction of the foreskin over the glans, also sometimes occurs, promoting balanitis, which should be treated as before, a syringe with a long point being used to introduce the washes under the prepuce.

Epididymitis.—About fifteen per cent. of all cases of gonorrhœa are complicated by the extension of the inflammatory process to the epididymis; it occurs only after the gonorrhœal process has attacked the posterior urethra. The extension of the disease may be marked by a chill and rise of temperature followed by pain in the testicle and cord, often very severe, and a rapid swelling of the epididymis. This usually remains stationary for several days, and then finally subsides, often leaving, in the head of the epididymis, a nodule which remains permanently. This condition is serious, inasmuch as it frequently blocks the vas deferens, and when it occurs on both sides it may render the victim sterile. During the acute attack the patient should rest in bed, and to this he readily assents. The application of poultices, painting the tumor with a ten-per-cent. solution of silver nitrate, or lightly brushing it with the white-hot cautery, care being taken not to burn the skin, are all useful in quieting the inflammation. The addition of a handful of fine-cut tobacco to the poultices is considered of value by many practitioners.

Folliculitis.—The minute glands of the urethra frequently become inflamed, forming small round tumors which open spontaneously through the skin or occasionally into the urethra. They should be treated by hot applications or by the inunction of mercurial ointment; or, if suppuration occurs, they should be opened and the cavity washed out with an antiseptic and packed with gauze.

Cowperitis.—The glands of Cowper may be infected in the same way, and the treatment is the same as for folliculitis.

Prostatitis.—The prostate gland may also become involved during the course of an acute posterior urethritis. The inflammatory process may be either follicular or diffuse. In follicular prostatitis the diagnosis is exceedingly difficult as the symptoms are identical with those of posterior urethritis. Examination by the rectum usually indicates small points of induration and tenderness on pressure. When the inflammation is diffuse, however, the symptoms are much more characteristic. In addition to the frequency of urination, perineal pain, and tenesmus, there is a feeling of fulness in the rectum, with pain on defecation, and occasionally ribbon-shaped fæces are passed. The finger in the rectum detects a throbbing, hot, tender tumor, the prostate, which may attain the size of an orange. Fever is usually present.

As a rule, resolution takes place under treatment, but suppuration may occur. In the latter event the patient will have a chill and there will be a marked rise of temperature; occasionally, also fluctuation can be felt in the tumor through the rectum. If not treated surgically the abscess may burst into the urethra or the rectum, or through the perineum. At times it will open into both urethra and rectum, leaving the patient with the horrible condition of recto-vesical fistula; or the pus may burrow between the layers of the pelvic fascia, and so cause septicæmia and death. The treatment of this condition is by hot rectal enemata, the application of leeches to the perineum, and hot sitz baths three or four times daily, the vesical tenesmus being relieved and controlled by the use of opium. When suppuration takes place the pus should be evacuated through a perineal incision and drainage established.

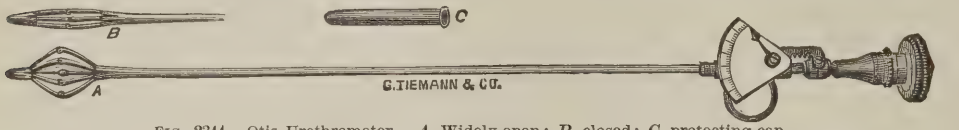

FIG. 2344.—Otis Urethrometer. *A*, Widely open; *B*, closed; *C*, protecting cap.

Vesiculitis.—Inflammation of the seminal vesicles occurs with greater frequency than has until recently been supposed. The symptoms are a feeling of weight and throbbing pain at the neck of the bladder, sexual hyperæsthesia, priapism, and seminal emissions. Exploration by way of the rectum reveals the fact that the vesicles are tender and swollen. Treatment is the same as for prostatitis.

Cystitis.—The gonorrhœal process rarely attacks the bladder proper, the inflammatory process being usually limited to the neck alone. When such an extension does take place, however, the results may be of a serious character. The cystitis, for example, may become chronic, or the inflammation may invade the connective tissue and muscular layers (parenchymatous cystitis), rendering the patient permanently disabled. After the acute symptoms have passed off, the bladder may be washed with only the mildest solutions, as boric acid in saturated solution, nitrate of silver, or potassium permanganate 1 to 6,000. At the same time urotropin should be administered internally.

Pyelitis.—This is a rare complication of gonorrhœa, but occasionally it does occur and may result in the loss of the kidney, though as a rule recovery finally takes place. The diagnosis can be made only with the microscope. Treatment: rest in bed, dry cups, hot fomentations and poultices over the region of the kidney, and the administration of diuretics and urinary antiseptics.

Gonorrhœal Rheumatism.—During the course of a gonorrhœa one or more joints may be affected and should be treated by the usual methods employed in synovitis. In rare instances the peritoneum, pericardium, or other distant organs may be invaded. For a detailed account of this complication consult the article on *Gonorrhœal Arthritis.*

CHRONIC GONORRHŒA.—When the discharge has lasted for a period longer than two months its continuance is due to the presence of some pathological condition in the urethra. As a rule, this will be found in the presence of stricture, a contraction of the meatus, or in localized infiltrated granular patches which fail to heal. The rôle which the gonococcus plays in the production of these infiltrations has been disputed, but in all probability it penetrates the deeper tissues and is the direct cause of the inflammatory deposit which subsequently becomes organized cicatricial tissue. Strictures which encroach so little upon the calibre of the canal as not to interfere in the slightest degree with its physiological functions are at the same time perfectly capable of indefinitely continuing a discharge once established, and are exceedingly apt to be overlooked by the surgeon. In a minority of cases of chronic gonorrhœa no stricture will be found to be present, the discharge being prolonged by the involvement of the sinuses and glands of the urethra, which are much more numerous and of greater depth than is generally recognized; by the presence of small neoplasms; by the involvement of the seminal vesicles; by the general condition of the patient; or, finally, even by a mixed infection of the tubercle bacillus. The discharge may be exceedingly profuse, or it may be so slight as to remain unnoticed by the patient, appearing only in the form of a single drop in the morning, or it may appear only in the form of threads and strings in the urine.

These threads, the so-called "Tripper Faden" of the Germans, consist of separate masses of purulent secretion exuding from the granular patches. Upon being washed out by the stream of urine, these masses are rolled up in the form of threads and appear as such floating in the urine. They consist of transparent cylindrical masses in which corpuscles and a few epithelial cells are embedded. The more compact these fibres appear the more pus they contain, but if they are transparent they consist for the most part of urethral epithelium with but little pus. The more epithelium there is in these threads the nearer the process is to a cure. The threads, which are principally composed of mucus and epithelium, have a tendency to float, while those composed chiefly of pus sink rapidly to the bottom of the glass.

Some authors hold that the location of the lesion can be diagnosed by the form of the threads. If they are short and thread-like, they are supposed to be formed in a gland duct; if long and thick, to arise from the urethra itself; and if short and lumpy, to come from the prostatic urethra. As they are in reality formed by the stream of urine washing out and rolling up into threads the secretion which originally had a flat, plate-like form, it is evident that we can form no satisfactory opinion, simply from their external appearance, as to what portion of the urethra they come from. When the microscope shows the presence of spermatozoa embedded in the substance of the thread, the probability is that it originated in the posterior urethra.

It is very important to locate the position and determine the character of the lesion upon which the continuance of the discharge depends. As has been said before, the most frequent cause is a urethral stricture, the presence of which may be determined by the use of the urethrometer or by means of graduated bulbous bougies.

The presence of areas in which a granulating or ulcerative process is going on, or of a neoplasm, can be definitely determined only by the use of the urethroscope, so that this instrument is exceedingly valuable in the diagnosis as well as the treatment of chronic urethral discharges.

Treatment.—No matter in what portion of the canal the disease may be located, the first indication for successful treatment is to remove all mechanical obstacles which stand in the way of a cure. All pathological narrowings should be divided by means of dilatation and urethrotomy combined, although in recent cases dilatation alone will often prove sufficient.

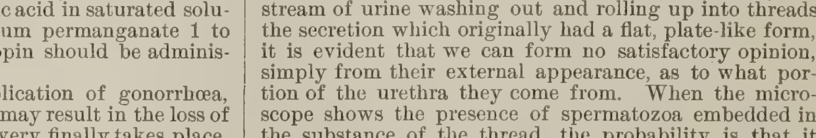

FIG. 2345.—Ultzmann's Syringe.

In the subsequent treatment injections similar to those employed in acute urethritis may be used, but they may be of greater strength and need not be used with so great frequency.

As in most cases of chronic gonorrhœa the posterior urethra is also involved, it will be found necessary to treat the entire urethra. This is best done by means of irrigations, in which the bladder is filled with fluid through a catheter, which is then removed and the patient allowed to eject the fluid in the same manner as if he were urinating; or the bladder may be filled without a catheter by the use of an irrigator and urethral nozzle as described in the treatment of acute posterior urethritis. The solutions best adapted are protargol, one per cent.; nitrate of silver or permanganate of potassium, 1 to 1,000.

When the posterior urethra is alone involved instillations of solutions of the nitrate of silver, of from five to ten per cent. strength, are very useful, from five to fifteen minims being introduced by means of the Ultzmann drop syringe.

A favorite method of treatment by Professor Ultzmann is the daily passage of a sound large enough to fill completely the urethra, the instrument being allowed to remain *in situ* for several minutes. These sounds should not be lubricated with vaseline or other oily substance, but with lubrichondrin, glycerin, or other substance which is soluble in water, as this mode of employing sounds is to be immediately followed by irrigation. In carrying out the latter procedure the patient should first be placed in the recumbent position, and then a short catheter—one that will reach only a short distance into the posterior urethra—should be introduced its full length. The syringe (capacity, 5 or 6 ounces) having previously been filled with the remedial solution, should next be connected with the catheter by means of a bit of soft india-rubber tubing. Then the fluid should be injected slowly into the urethra and on into the bladder. If the latter easily contains a large amount of fluid the syringe may be filled a second and even a third time. It will be known that the catheter is in the correct position if the fluid flows easily into the bladder and does not run out of the catheter when the syringe is removed; for if the instrument extended no farther than to a point in front of the compressor the fluid would flow back along the sides of the catheter and come out at the meatus. When the method described above is carried out successfully, the posterior urethra receives a double washing: first, by the introduction of the fluid through the catheter, which is provided with several slit-like openings instead of a single eye; and secondly, when the patient expels the large amount of fluid which has been introduced into the bladder.

The solutions used by Ultzmann and which are very efficacious are based on an ascending scale. He employs them in the following manner:—

First day, a solution of zinc sulphate, alum, and carbolic acid, each one part, to one thousand parts of water; second day, the same, 1 to 500; third day, permanganate of potassium, 1 to 2,000; fourth day, permanganate of potassium, 1 to 1,500; fifth day, permanganate of potassium, 1 to 1,000; sixth day, nitrate of silver, 1 to 2,000. The silver is strengthened in the same ratio as the permanganate of potassium, not being used in greater strength than 1 to 1,000.

I give this graduated method of Professor Ultzmann which has been standardized by him, and which has proved most serviceable in my hands, although I am inclined at present to substitute some of the later silver preparations for some of the solutions used by him. One of the great advantages of this method is the definite rule of progression, which allows the patient to become used by degrees to the increasing strength of the remedies employed. This rule should not be too closely adhered to, however, and if the patient complains greatly at any time, the progression should be made more gradually.

After one has reached the higher solutions of the silver nitrate, in carrying out the plan just described, it is well to resort to the instillations into the deep urethra as before described. They may be repeated advantageously on every second or third day.

The Urethroscope.—One of the most satisfactory methods of treating the lesions of chronic urethritis is by making direct applications to the diseased urethral mucous membrane by means of the electro-urethroscope. Within the last few years this instrument has been so simplified and improved that it can no longer be regarded as being for the use of the specialist alone, but should form a part of the armamentarium of all those who undertake the treatment of diseases of the urethra.

At the same time a certain amount of practical experience is necessary in order to recognize the various pathological conditions encountered, and this can be acquired only by the actual use of the instrument, as no amount of description can more than indicate the exact appearances of the urethral field.

The tube used should be the largest which will pass the meatus, and occasionally it will be found necessary to divide the latter in order to pass an instrument which will give a satisfactory view. This should be done, if possible, a week or so before the urethroscope is used, so that time is allowed for healing to take place. When this cannot be done it is often feasible rapidly to dilate the meatus with solid sounds sufficiently to allow the passage of the urethroscopic tube without bleeding.

If the anterior urethra alone is to be examined, one of the shorter tubes should be chosen, lubricated for its entire length with lubrichondrin or glycerin, and gently passed on as far as to the bulbo-membranous junction. The tube should be held between the index and middle finger of the right hand below the disc, the thumb pressing firmly on the handle of the obturator to prevent its being displaced. The left hand grasps the glans penis between the index finger and thumb.

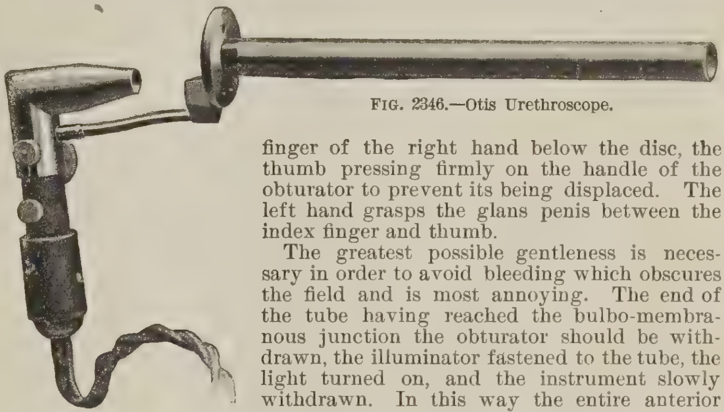

FIG. 2346.—Otis Urethroscope.

The greatest possible gentleness is necessary in order to avoid bleeding which obscures the field and is most annoying. The end of the tube having reached the bulbo-membranous junction the obturator should be withdrawn, the illuminator fastened to the tube, the light turned on, and the instrument slowly withdrawn. In this way the entire anterior urethra may be carefully observed bit by bit. Blood or discharge at any point should be removed with the swab, and applications can be made to any diseased areas which may appear in the field.

The examination of the deep urethra is an exactly similar procedure, except that it is necessary to pass the triangular ligament with a straight instrument, and therefore somewhat greater skill will be needed on the part of the operator.

In conclusion I may state that the urethral mucous membrane is exceedingly delicate and resents any but the most gentle advances, and that it is especially necessary to remember this when contemplating any instrumental procedure. For this reason, moreover, it is not infrequently the case that we see obstinate chronic discharges which owe their continuance to over-treatment, and which would get well if left entirely alone. It is also well to remember that the urethra may become tired of any one form of treatment if too long continued and that a change is frequently necessary if a cure is to be effected. *William K. Otis.*

GONORRHŒAL ARTHRITIS.—(Synonyms: Gonorrhœal Rheumatism; Gonorrhœal Synovitis; Blennorrhagic Rheumatism.) The term "rheumatism," as applied to this disease, is objectionable, implying a relation to ordinary rheumatism which does not exist.

DEFINITION.—Gonorrhœal arthritis is inflammation of a joint or of joints, due to the gonococcus of Neisser.

PATHOLOGY.—Gonorrhœal arthritis is to be regarded as one of the commonest manifestations of a general infection of the circulating medium with the gonococcus or its toxins. Other manifestations are endocarditis, myositis, disease of the tendons and fasciæ, and of the eye. According to Taylor, it is probable that septic absorption in urethritis does not take place until the infection has reached the posterior urethra. The gonococcus has been cultivated from the blood, first, I think, by Hewes in 1894, and later by Welch. Gonorrhœal arthritis, then, always implies infection of the circulating medium.

The joints show varying degrees of inflammatory change. There is first a simple synovitis with more or less fluid—serous or sero-fibrinous. Later the fluid may become purulent. The process tends strongly to extend to the fibrous and ligamentous structures about the joint, resulting in a periarthritis. Adjacent bursæ and tendon sheaths are very commonly involved.

Bacteriological studies, by the microscope and by cultures, give varying results. The gonococcus may be found alone or pus organisms may be found alone—the latter in cases with purulent exudation. The fluid may contain both gonococci and pyogenic microbes, or it may be sterile. It is probable that the gonococcus is always present at first and that there may be a simultaneous or, more often, subsequent infection with pus organisms. In the cases in which no organisms are found, it is probable that the gonococci have early disappeared. In some such cases the arthritis may not be due to gonorrhœa at all. Some cases may be due to the toxins of the disease, without any bacteria, like the joint affection following the use of diphtheria antitoxin. But probably in most cases the gonococcus is at some time present in or about the joint.

As a result of severe and protracted cases fibrous adhesions are prone to result. There may be almost complete fibrous ankylosis. This is especially apt to occur as a result of repeated attacks of arthritis from repeated reinfections of the urethra, or when the joint has been long immobilized. Changes resembling those of chronic rheumatoid arthritis may result. Nearly every joint in the body may be permanently damaged.

Etiology.—Enough has already been said in speaking of pathology to indicate the etiological relationship of the disease to the gonococcus. It is always a sequel of local infection with this organism—usually urethritis. It has also resulted from vulvo-vaginitis in children and from gonorrhœal infection in which no urethritis existed, as in ophthalmia neonatorum.

No age or sex is exempt, but it occurs most commonly in adult males—in other words it is commonest where gonorrhœa is commonest. Exposure to cold and trauma act only, if at all, by increasing susceptibility. Individual susceptibility varies greatly. Some men have it with every new gonorrhœa. Others, the majority, never have it at all. Persons subject to ordinary rheumatism or having the rheumatic diathesis do not show any special susceptibility.

Distribution.—Arthritis occurs in about ten per cent. of all cases of gonorrhœa (Taylor). The commonest site is the knee, and next the ankle, wrist, fingers and toes. While it is commonest in the larger joints any joint may be involved—even the jaw, chondrocostal, intervertebral, sacro-iliac, sterno-clavicular, and crico-arytenoid. In about forty per cent. of the cases but one joint is involved. But it may be polyarticular, and in fact a single attack may involve nearly every joint in the body.

Symptoms.—The disease may begin in almost any stage of gonorrhœa, most commonly about the fourth week. According to Taylor it seldom begins in acute gonorrhœa earlier than the second or third week, when the posterior urethra is involved. It may be delayed for months, till the urethritis has run on into a chronic gleet.

The onset is rapid—beginning with slight pain and stiffness. Premonitory fever and malaise are rarely present. As a rule general symptoms are mild throughout. Fever is slight in most cases. Rarely there is delirium or profound sepsis. Sweating is not a prominent feature. As the case goes on anæmia and debility are marked, especially when there have been unusual pain and confinement.

When the inflammation is at its height the appearance of the joint is quite characteristic. There is much swelling, due to fluid in the joint cavity and to œdema of the surrounding soft parts. Owing to the tendency of adjacent bursæ and tendon sheaths to share in the inflammation the swelling oftens extends up and down the limb for a considerable distance. There is not often great redness and the tenderness is usually less than in ordinary acute rheumatism. So, where the distribution is such that locomotion is not prevented, many cases are treated as hospital out-patients. Pain varies greatly: it may be almost lacking, so that the patient complains mainly of stiffness, or so severe as to prevent sleep and require morphine.

The course of the disease is slow and tedious. Once involved, the joint usually remains so till the case is over—there is no marked tendency to jump about from joint to joint. A large joint seldom recovers in less than from four to six weeks. The acute process may subside and leave a hydro-arthrosis lasting for months in spite of all treatment. In some cases complete resolution may never occur, the joint remaining more or less ankylosed.

In the so-called arthralgic form of gonorrhœal arthritis there occur, in the course of a gonorrhœa, fugitive pains in the joints and muscles, without any active inflammatory process. The symptoms may be very persistent.

When the joint becomes infected with virulent pus bacteria the case becomes like any purulent arthritis. Fortunately this is not common. If prompt surgical relief is not afforded, and there is a general infection, such a case shows the symptoms of pyæmia—chills, irregular fever, progressive asthenia, and death.

Relapses do not occur unless there is a new urethral infection. One attack does not confer immunity. Indeed, some individuals seem to have it nearly every time they get the clap.

Complications.—Bursitis and teno-synovitis are not uncommon. Involvement of the muscles, and of the fasciæ, especially of the palm and sole, sometimes occurs. The eye may be involved by means of organisms or toxins brought by the blood, a condition to be distinguished from the gonorrhœal conjunctivitis due to infection from without. Endocarditis and general infection with the gonococcus or with pus organisms is a very serious complication.

Diagnosis.—Gonorrhœa is common, and so are other forms of arthritis. Therefore even when joint inflammation occurs in the course of a urethritis it does not follow that the disease is gonorrhœal arthritis. The diagnosis can be made with absolute certainty only when the gonococcus is recognized in the fluid from the joint cavity. The distinguishing clinical features of the affection are the tendency to involve one or a small number of joints; its persistent character, long duration, and failure to jump from joint to joint; the usually slight general disturbance, the fusiform character of the swelling from the tendency to invasion of tendon sheaths, and the association with other manifestations of gonorrhœal infection.

Ordinary acute articular rheumatism usually involves many joints, shifting about from one to the other, the first ones recovering as others become involved. There are more elevation of temperature and greater redness, pain, and tenderness than in the gonorrhœal disease, and the bursæ and tendon sheaths are not apt to be invaded. These characters, together with the effects of treatment, explain why it is rarely mistaken long for gonorrhœal arthritis, even when coincident with gonorrhœa.

Long-continued cases may give rise to a suspicion of tuberculosis, especially when the joint in question is the hip. Gout and simple or traumatic synovitis should also be mentioned. In purulent cases it is of little moment whether the disease is the result of gonorrhœa or not, as the course and treatment are identical.

Prognosis.—Complete recovery is the rule. But the disease is an obstinate one and the treatment is not satisfactory. There is often danger of ankylosis, especially when the condition is recurrent. The patient should be warned that a new gonorrhœa is likely to mean a new arthritis, and that each new arthritis is likely to leave the joint in a less perfect condition than before. When the inflammation is purulent and associated with endocarditis from mixed infection with the streptococcus the prognosis is of course unfavorable.

Treatment.—It is of the first importance to remedy, by measures adapted to the individual case, the primary gonorrhœal focus. According to Taylor especial attention should be given to the posterior urethra.

Salicylates and alkalies are of no value in gonorrhœal arthritis. Yet on the chances of an error in diagnosis the writer is of the opinion that in many cases a vigorous trial should be given them—on the principles laid down for ordinary acute rheumatism. Potassium iodide has been much used, but is probably devoid of any specific action. The same may be said of quinine and methylene blue. Probably iron, arsenic and other tonics, together with fresh air and plenty of good food, are the best general measures.

During the acute stage the patient should be kept in bed and the part at rest. If pain is severe it may be relieved by an ice-bag. Immobilization by splints or plaster usually gives great relief. But immobilization should be as brief as possible, owing to the danger of ankylosis. Later on, "baking" the joint in hot, dry air or counter-irritation by means of tincture of iodine, vigorous blistering, or the cautery may hasten resolution. If ankylosis threatens massage and passive motion are indicated after the acute process has subsided.

If the effusion persists the joint may be aspirated with or without the subsequent injection of corrosive sublimate solution 1 to 2,500, carbolic acid 1 to 50, or iodoform emulsion. This should of course be done under the most rigid antiseptic precautions. It may be repeated if necessary. It has given excellent results in competent hands. For suppurative cases prompt and vigorous surgical measures are demanded. *Ralph C. Larrabee.*

GORDON SPRINGS.—Lake County, California. These springs lie in Cobb's valley, about half-way between Calistoga and Lakeport. They are romantically situated in the heart of a mountain and forest region. The climate is very fine. The location is about 3,000 feet above the sea-level. The principal spring flows about 300 gallons of water hourly, having a temperature of 100° F. The waters are sparkling, alkaline, and have antacid and aperient properties. Following is Winslow Anderson's analysis:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	20.75
Sodium carbonate	3.19
Sodium sulphate	8.62
Potassium carbonate	.73
Magnesium carbonate	6.14
Magnesium sulphate	10.93
Calcium carbonate	11.16
Calcium sulphate	23.46
Alumina	3.55
Silica	2.27
Organic matter	Trace.
Total solids	90.80

Carbonic acid gas, large excess.

The waters have considerable reputation in chronic albuminuria and in cystitis; they are also valuable in acid dyspepsia. A pleasant resort has been established, and it is worthy of remark that persons suffering from chronic bronchitis, catarrh, asthma, and the early stages of consumption do well at this eyrie among the pines. *James K. Crook.*

GOSSYPIUM. See *Cotton.*

GOUNDOU. See *Henpuye.*

GOUT.—The exact nature of gout is still unknown. One might with honesty begin a description of it as Sydenham did more than two hundred years ago: "Either man will think that the nature of gout is wholly mysterious and incomprehensible or that a man like myself who has suffered from it thirty-four years must be of a slow and sluggish disposition not to have discovered something respecting the nature and treatment of a disease so peculiarly his own. Be this as it may, I will give a *bona fide* account of what I know. The difficulties and refinements relating to the disease itself and the methods of its cure, I will leave for time, the guide to truth, to clear up." Numerous hypotheses are described for the consideration of students of the subject, and our knowledge of the malady has greatly increased since Sydenham wrote, but its mystery has not yet been fathomed.

Gout has been recognized as a malady from the earliest times. It was well described by Hippocrates (350 B.C.). Five hundred years later Galen ascribed its origin to noxious substances as "black bile," "blood," or "phlegm" about the joints. He believed the tophi were produced by their consolidation.

In the middle ages, according to the prevailing theory, the disease was believed to originate from "tartar," which was supposed to come from wine that had been drunk and which formed incrustations about the joints, like those found in wine casks. This theory was disproved when Schule (1776) showed that tophi were composed of urates.

Gout has been thought contagious. This was the belief of Boerhaave. Cullen advocated a nervous origin for the malady. In 1848 Garrod's thesis on "The Blood and Urine in Gout, Rheumatism and Bright's Disease" established the existence of an excess of urate of sodium in the blood and ascribed to it a causative relationship to the malady. From that time to near the present a majority of pathologists and clinicians have regarded gout as due to an excess of uric acid in the blood, and they have described those prone to it in its typical or irregular forms as of the uric-acid diathesis.

As our clinical knowledge of gout is comparatively perfect, it seems best, therefore, to describe its symptoms first and to consider its nature, causation, prophylaxis, and treatment later. Cases of gout are clinically placed in three groups: (1) Acute gout; (2) chronic gout; (3) irregular gout.

Acute Gout.—Premonitory symptoms are commonly observed. They are usually those of gastric indigestion, such as flatulence, sourness of the stomach, a feeling of fulness in the epigastrium and constipation, or irritability of temper, restlessness at night, dull headache, or melancholia. Twinges of pain in the small joints of the feet and toes are often felt for several days before the acute attack occurs.

Acute gout commonly makes its onset in the early morning hours, the patient awakening with intense pain in the metatarso-phalangeal joint of one big toe, oftenest the right. The pain is severe but becomes more intense during the next two or three nights. It is described as a sensation of squeezing. The feeling is as if the toe were in a vice. Throbbing, burning, and sometimes a lancinating pain, are also complained of. At first the veins about the affected part are unusually prominent. Soon, however, the joint swells uniformly and the skin becomes slightly red and glossy. It is exquisitely tender, so that even the weight of the bed-clothing is a source of increasing distress. The slightest motion of the joint also elicits a cry of anguish from the sufferer. Bodily temperature is increased, often only a little, sometimes to 102° or 103° F.

Often such attacks of podagra begin with a chill, or at least with chilly sensations and rise of temperature. After daybreak the pain subsides, fever lessens, and the patient may doze for a time. Although the intense pain is less, the swelling remains in the affected joint and it is kept immobile because of the pain which movements of it provoke. Toward night the symptoms again become more intense. So long as the attack lasts each night is made sleepless by an aggravation of the characteristic symptoms of the malady. Patients therefore become greatly wearied, even much debilitated by sleeplessness, suffering, and inability to maintain good nutrition, for appetite is lacking and digestion is impaired. An attack such as this lasts for from one to several weeks. Gradually the symptoms grow less intense, the swelling of the joint subsides, mobility returns, and often after an attack a patient will feel unusually well. Sometimes during convalescence the skin over the joint which has been affected peels off.

Attacks are frequently prolonged by one great toe after the other being involved or by other joints than those of the toes being attacked. Although the large toes are commonly first involved, the fingers, and later the large joints, may be as well.

The urine is frequently concentrated and deposits urates. Traces of albumin or sugar are also sometimes found in it.

Acute gout is apt to occur in the late winter and early spring. It recurs at variable intervals; it may be annually or at longer or shorter periods. Usually after several attacks it begins to recur more and more frequently and the individual's health becomes permanently impaired. It is extremely rare that only one attack occurs in a lifetime.

CHRONIC GOUT.—Chronic gout results from several acute attacks. The joints which have been affected become permanently swollen or deformed by uratic deposits in the fibrous tissue about them, and are commonly stiffened and sometimes permanently immobile. Tophi, as these deposits of urate of sodium are called, are also found upon cartilages, on synovial membranes, and the sheaths of tendons. The cartilages of the ear are affected with especial frequency. Nodules are also formed along the course of tendons on the back of the hands and feet. Uratic deposits within joints where they first take place are invisible and do not always cause noticeable enlargement of them, but rarely last long before the neighboring ligaments are involved. Intracapsular deposits can sometimes be detected by a grating noise produced when the rough surfaces are moved upon one another. When joints are impaired in usefulness the muscles which control them atrophy. In severe cases the skin over the tophi becomes necrotic, sloughs, and exposes the "chalk stones," permitting them to crumble or to be easily removed. This, however, rarely happens until the lesions are so extensive that in spite of the partial removal of a source of stiffness and deformity a renewed usefulness of the joint is impossible. Patients, typifying the severest cases, are helpless invalids and constant sufferers. In mild cases there is some stiffness at all times but there is not complete helplessness. Frequent acute exacerbations increase the pain which these patients suffer. They are accompanied by the usual symptoms of acute gout, and frequently are complicated by uræmia, pleurisy, pericarditis, or other visceral lesions.

The digestive disorders which so often precede and accompany acute attacks are present more or less constantly in chronic cases. Flatulence, acid indigestion, constipation, and gastric discomfort are the commonest symptoms of them. They are associated with headache, neuralgia, lassitude, mental depression, and irritability. Eczema and urticaria are common skin complications. In chronic gout the kidneys are usually involved and gradually become contracted, producing the symptoms which are peculiar to interstitial nephritis. The arteries are also liable to atheromatous changes and the heart to hypertrophy and ultimate enfeeblement.

The digestive and nervous symptoms are aggravated by an inability to take exercise, due to the joint deformities. Pain causes sleeplessness and exhaustion. Indigestion contributes to malnutrition, and it is usual for those who have chronic gout slowly to lose flesh and strength.

In spite of this chronic state of disease, surprising as it may seem, life is often prolonged into the period of old age. Indeed, it is usual for the malady to last for many years. Patients commonly show remarkable mental vigor.

Occasionally in the midst of acute articular gout or acute exacerbations of chronic gout, the acute arthritis suddenly disappears or greatly lessens, but is replaced by visceral complications. Such cases are often described as cases of retrocedent or suppressed gout. The visceral complications may be inflammations or other lesions of the bronchi, lungs, pleura, nasopharynx or larynx, of the stomach, intestines, heart, kidneys, brain, or peripheral nerves.

Epilepsy, delirium, and insanity are rarely a part of the disease. But neuralgias are common. Of these sciatica is the form most frequently observed. Gastralgia is also of frequent occurrence. It is associated with the usual indigestion of the affection. Of all the visceral complications of gout those of the circulatory system and kidneys are the most dangerous. Myocarditis is common. Endocarditis and pericarditis are of less frequent occurrence, but angina pectoris is often seen. Aortitis and aneurisms are other common circulatory affections. Functional irregularity of the heart and tachycardia are disturbances of frequent occurrence. Hypertrophy of the heart muscle is the rule in all chronic cases.

Interstitial nephritis develops sooner or later in those who suffer from chronic gout. It or uræmia growing out of it is a common cause of death. Indeed, fatalities rarely result from uncomplicated gout.

IRREGULAR GOUT.—Irregular gout is difficult to describe and often to recognize with certainty. Some of the viscera or the skin may develop lesions which the gouty are known to be prone to, and their sequence may make a diagnosis possible or their nature may be recognized by reasoning by exclusion. Irregular gout is very much commoner than classical gout. It frequently occurs in the women in families in which acute and chronic gout attacks the men.

In early life urticaria is common in those having a gouty diathesis, or the lithæmic state, and in late life chronic eczema is. Asthma, bronchitis, renal calculus, and diabetes mellitus are other maladies to which these same individuals are liable. Flatulent, acid indigestion and constipation associated with myalgias and neuralgias, with hemicrania or with mental depression or irritability are particularly significant of a tendency to the disease. Hot and itching feet at night and hot and itching eyeballs by day are common symptoms in women. Any of the various visceral lesions already mentioned may develop in those inclined to gout, although podagra or other articular evidence of the ailment may be wanting. Sooner or later the cardio-vascular and renal disorders incident to chronic gout develop in a majority of those who suffer long with irregular gout. Iritis, glaucoma, and hemorrhagic retinitis are common complications of the malady.

Urine.—Between attacks of acute gout the urine may be normal. During an acute attack it is concentrated and diminished in amount. On standing, a pink or "brick-dust" sediment is thrown down. Although concentrated a diminished amount of uric acid is usually voided. When convalescence is established a moderate excess of this ingredient may be eliminated. In chronic gout the urine is commonly copious, of low specific gravity, and contains a diminished quantity of uric acid. However, not infrequently gouty men are found who habitually void normal quantities of uric acid. When interstitial nephritis exists the urine, besides being copious and of low specific gravity, contains small amounts of albumin and hyaline and fine granular casts.

Blood.—During acute attacks and while the disease is chronic an excess of urates can be demonstrated in the blood. But in the early stages of the disease, during the intervals between attacks, the blood is quite normal. Uric acid can be demonstrated in the serum of those who have gout by adding ten or twelve drops of acetic acid to a few cubic centimetres of blood or of serum obtained from a blister produced upon the skin. A thread must be immersed in this mixture of serum and acid for twenty-four or forty-eight hours, when it will be found to be covered with crystals of uric acid.

DIAGNOSIS.—A diagnosis of acute gout can usually be made with ease, so distinct and characteristic are the symptoms. However, I have known a first attack to be mistaken for a trauma. But the development of symptoms characteristic of the course of the malady will correct such an error. It is rarely confused with acute articular rheumatism. In this last disease the large joints or numerous joints are involved from the beginning, the temperature is usually higher, and the skin is bathed with perspiration.

The presence of tophi makes it possible to distinguish chronic gout from chronic rheumatism and other forms of chronic arthritis. The history of numerous acute attacks is also a help to a diagnosis.

Irregular gout is more difficult to recognize, but attention to the symptoms described above and to their interchangeability in different attacks in the same person and connection, commonly with characteristic digestive disturbances, makes a diagnosis possible.

ANATOMICAL CHANGES.—The evidences of inflammation in the tissues involved are not different from those of other forms of inflammation, except that deposits of urates are observed with them. At first these deposits occur in the articular cartilages. They are seen as white dots or lines beneath the surface. Later they increase in size, coalesce, and produce destruction of the surface. The cartilages and capsules of joints, the fibrous tissue in bursæ, tendons, the periosteum, and the auricles are the structures in which tophi are oftenest found. The aorta is frequently thickened in spots by uratic deposits, as are sometimes the coronary arteries. An increase of fibrous tissue in the myocardium is also occasionally observable. The kidneys are commonly contracted and exhibit the conditions peculiar to interstitial nephritis. Lines of urates can be seen in many cases, both in the cortex and medullary portions of these organs. These deposits occur in parallel lines, partly in the uriniferous tubules, but mainly in the interstitial tissue between them. The liver is sometimes found in a condition of slight interstitial hyperplasia.

Theories as to Nature.—Although a clinical knowledge of gout has been possessed by physicians since the earliest times, its exact nature and cause are to-day unknown. A variety of hypothetical explanations have been offered, but none of them has as yet been established as correct. Garrod's theory has for many years been accepted by the majority of the profession. According to him, gout is due to an excess of urates in the blood and fluids of the body, from which they are deposited in certain tissues because of a diminished alkalinity of them. The excess of urates, it has been supposed, is due in part to excessive production because of disturbed metabolism, and in part to imperfect elimination. That the renal epithelium has a power of selecting certain substances for elimination is a demonstrated fact, and it has been supposed by some that in gout it refuses to excrete uric acid in the normal or necessary amounts. Ebstein modified the theory of Garrod by advocating that an excess of uric acid was produced in muscles and bones because of a peculiar local metabolic anomaly which is usually inherited. The deposit of urates in cartilage and fibrous tissue he accounted for because of the naturally slow circulation of blood through them, which, when it contains an excess of uric acid, causes a cellular necrosis in those tissues. The necrosis always produces a local acidity, and the alkaline urates of the blood are then precipitated as comparatively insoluble acid urates.

The uric-acid theory has also been modified by the hypothetical explanation that uric acid is an intermediate product in the transformation of waste nitrogenous matter into urea, a transformation made in the liver, and that an excess of uric acid in the blood results from such a derangement of hepatic functions as causes the formation of a lessened amount of urea and a proportionately larger amount of uric acid. The observed coincidence of gout and digestive disturbances has given color to this theory. Of late, however, physiologists have become convinced that uric acid is not an intermediate step in the formation of urea from proteid. Indeed very recent researches (Kossel, Horbaczewski) have led physiological chemists to believe that uric acid is derived from nucleins and not from other parts of cells.

Unfortunately for all these uric-acid theories gout cannot be produced experimentally by injecting uric acid into the blood or by preventing its elimination through the kidneys. Nor do the phenomena of the disease arise in other ailments, notably leukæmia, in which uric acid often exists in the blood in quite as large quantities as in gout. Experiment affords us no evidence that toxic properties are possessed by uric acid even when it is introduced into the blood in much larger amounts than have ever been found in gout itself.

Another theory which has not in the last fifty years had so many supporters as the uric-acid hypothesis or so many as at the end of the eighteenth century, but which nevertheless at all times has had influential advocates, is the theory of its nervous origin. According to it, gout is due to a disturbed metabolism, a fault of the system in which the chemical balance is deranged. The metabolic processes are presumed to be under the control of the nervous system, therefore such a perversion of them as occurs in gout primarily must be due to a disturbance of nerve centres. Just what change takes place in the central nervous system is not conjectured. Those who believe in a nervous origin of gout base their faith chiefly upon the following points: (1) Its frequent inheritance. (2) The effect of psychic disturbances, such as anger or mental depression, in provoking its attacks. (3) A tendency to neuralgia and myalgia in such patients. (4) Influence of barometric changes. (5) Joint involvement, which is common to many nervous diseases. (6) Many neurotic manifestations observed in other members of the family in which gout appears.

In 1884 Gaucher discovered that the injection of xanthin and hypoxanthin into healthy animals caused changes in the structure of the kidneys, similar to those of interstitial nephritis. More recently others have confirmed these observations and found that the xanthin bases will produce various nervous phenomena as well as high arterial tension and ultimately arteriosclerosis.

Horbaczewski, who in 1891 showed that uric acid is probably derived from nuclein, has also gathered evidence to show that xanthin and hypoxanthin or the alloxuric bases are to blame for the phenomena of irregular gout or lithæmia rather than the urates. It is true that uric acid in the form of biurate of sodium constitutes the tophi of gout and produces local deformities and sometimes inflammation, but in the form of a soluble, alkaline, quadriurate in which it exists in the blood it is not toxic.

Although gout has been supposed by some to be an infectious disease, there is no adequate evidence that such is the case.

Causative Conditions.—It is quite evident from this brief review of the leading hypotheses advanced to explain the causation of gout that we are to-day about as ignorant as our predecessors a century or two ago were. What knowledge we possess to-day is negative, that is, disproves theories that have been widely held. Nevertheless, much is known of the conditions under which gout is likely to arise. Heredity plays a large part in its production. According to Garrod seventy-five per cent. of all cases inherit the disease. Oftentimes the habits of families which their inherited environment produces also predispose them to it. But gout may be acquired as well as inherited. Acute and chronic gout are rarely seen in this country, but irregular gout is common and is increasing. Gout occurs oftenest in England, next in frequency in France and Holland, less in Germany and rarely elsewhere in Europe. Symptoms of it have been observed at all periods of life, but its onset occurs in much the largest proportion of cases between the thirtieth and fortieth years. Initial symptoms are extremely rare in infancy, childhood, and old age. Women are attacked less frequently than men, at least with the symptoms of prodagra and chronic gout. Insufficient exercise, and what amounts to the same thing, a deficient supply of oxygen, are important factors in creating a disposition to the ailment. A sedentary life causes the inhalation of relatively a small amount of oxygen. Shallow breathing, which is cultivated under the circumstances, lessens the vigor of the lymphatic and venous currents which carry off waste matters from the viscera, and causes a torpidity of liver and digestive organs. Lack of exercise also causes the same interference with vigorous metabolism in the voluntary muscles. When people live or work in overcrowded rooms they are sure to feel the need of oxygen. Virchow has laid stress upon the frequent production of tophi in the joints of the poor who live under these conditions. Since the earliest times it has been admitted that eating unduly large quantities of food will produce the ailment in many persons. Especially is this true of the use of large quantities of meats rich in extractives, or cooked with rich gravies and sauces. Although oftenest too much food, that which is too rich, and too little exercise together cause gout, rare cases have been observed in which an acute attack was provoked in those disposed to it by too little food and too much exercise. In these latter patients a lowering of vitality by underfeeding and overworking excited the ailment. The habitual use of fermented liquors is a most common and universally recognized cause of gout. It is difficult to explain the mode of action of these liquors. It is not merely the alcohol which they contain, for the users of distilled liquors are much less prone to the disease than are the users of fermented beverages. Nor is it an acid, nor sugar, nor, as far as we know, any one ingredient in beers and wines which makes the drinkers of them so liable to develop gout. Often a few glasses of wine will awaken symptoms of the malady in those who are susceptible to it. It may be that the disturbances of digestion which overeating and the use of fermented liquors cause are more to blame than individual articles of food or beverages. Mental depression such as grief and anxiety or prolonged mental exertion are also frequent predisposing causes. They may help to produce their ill effects by making digestion slow and disturbing the functional power of the organs which play a part in it. It is well known that lead workers are especially liable to symptoms of gout as well as to arteriosclerosis and interstitial nephritis.

Many of these conditions which predispose to the disease act together, that is, simultaneously upon individuals. Many of them are also the exciting causes of acute outbreaks of the ailment. Exposure to cold, great fatigue, anything which lowers the vitality for the moment may be an exciting cause for those who are susceptible.

PROPHYLAXIS.—A knowledge of the conditions which dispose the gouty to attacks affords us a key to its prophylactic treatment. Good hygienic surroundings, daily sufficient exercise (often large amounts are required), moderate eating, and freedom from undue anxiety, worry or mental labor, are the best prophylactic measures.

TREATMENT.—Little can be done to shorten acute attacks of gout, but the pain attending them may be lessened by suitable treatment, and a great deal can be done to prevent a recurrence of acute attacks by instituting a proper regimen.

It is impossible to remove the inherited fault of nutrition, but it is possible to retard the development of symptoms. Temperance must be taught as the cardinal rule of life, abstemiousness in eating, drinking, the enjoyments of the pleasures of life, or the inclination for mental work. Overeating, even the most moderate kind, must be avoided. A varied diet may be permitted, provided it includes foods which are simply prepared and easily digested, and provided they are eaten in moderate quantities.

When gout is fairly established, not only must temperance be insisted upon, but certain articles of diet must be forbidden. These are sweets, confections of all kinds, fats, articles cooked with much fat, game, and the richer meats, especially when dressed with rich sauces. Vegetables, rich in oxalates, ought also to be avoided by the gouty.

These patients should eat fairly varied foods and the diet should be well balanced, containing a normal proportion of albumin, carbohydrates, and fats; and the individual articles of food should be so prepared as to be most easily digested. Meat may be eaten moderately, but green vegetables, certain fats, and cereals, may be taken generously. The diet for those who are gouty must not be so restricted as to lessen their vitality. A milk diet has been urged as the best for the prevention of outbreaks of gout in those disposed to them; but milk, unless used in excessively large quantities, is not sufficiently nutritious; and while it may well be used as an important element of food it should not be the only article taken by the gouty.

Soups should be forbidden when the symptoms of goutiness are clearly manifested, but they may be taken in small amounts by those inclined to this ailment. Whenever they are used, they should be entirely free from fats, and preferably should not be made with a meat stock. Eggs, oysters, and clams may also be eaten, but lobsters, crabs, and shrimps are not to be recommended. Most fish can be eaten without harm, especially such as bluefish, whitefish, perch, shad, bass, and trout; but fish richer in fats and those that are smoked and salted, such as salmon, mackerel, halibut, and cod, are not so wholesome. Rich sauces should always be avoided. Meat should be eaten not oftener than once daily, and generally roasted or broiled. Those which are most to be avoided are pork, veal, game, and salted or smoked meats. Fat should be used in very moderate amounts except butter which can be used with a reasonable degree of freedom, and cream in moderation. Such carbohydrate foods as bread, rice, sago, tapioca, oatmeal, and cracked wheat may be eaten generouly, but pastries, hot breads, pancakes, and other articles of a similar kind, which are liable to form doughy masses in the stomach during the period of gastric digestion, should be avoided.

Sugar is not wholesome for the gouty. Such vegetables as rhubarb, tomatoes, radishes, spinach, cabbage, and, if they cause flatulence, baked beans, should be avoided.

The following green vegetables may be used freely: peas, stringbeans, corn, potatoes, turnips, carrots, parsnips, celery and celery plant, cauliflower, artichokes, broccoli, salads, cucumbers, and egg plant. Of the fruits, the following are best adapted for the use of these patients: pears, apples, raspberries, blueberries, blackberries, and oranges; but grapes, bananas, prunes, strawberries, and melons are not so wholesome. Pickles and condiments are to be avoided at all times.

Eating between meals should not be permitted. Gouty patients should be taught to eat slowly and to masticate their food carefully.

Especially should those inclined to gout avoid eating a large variety of food at one meal. Simplicity in diet as well as temperance in eating must be taught them. The variety which we all crave should be furnished by changes in food from meal to meal and from day to day.

Although by clinicians generally red meats are forbidden those who have chronic gout, cases have been successfully treated upon an almost exclusive meat diet. Salisbury steak, a little lettuce or spinach, and stale bread, varied occasionally by chicken, squab, eggs and fish, have constituted the entire list of foods of these patients. The uniformity of the food and the ease of its digestion have prevented abnormal fermentations in the gastro-intestinal tract just as an exclusive milk diet will do. This is the secret of success in such cases.

In the midst of acute attacks it is best to administer little of any kind of food. Milk is the best staple article and may be the only one. Gruels and eggs may also be eaten, and oranges and lemons may usually be permitted.

Tea and coffee in small amounts and with no, or very little, sugar, may be used by those who are predisposed to gout, provided they have no acute symptoms of the disease or of indigestion; but if digestion is slow, or there are other symptoms of gout or goutiness, these beverages should be forbidden.

It is universally admitted that alcoholic beverages of all kinds are harmful. Even in very small amounts they will, not infrequently, provoke attacks of gout. The degree of tolerance of alcoholic beverages by those who are gouty is, of course, very variable. It is not necessary, in order to provoke gout, that these beverages should be taken to the point of intoxication. Indeed the habitual drunkard rarely develops symptoms of the disease, but it occurs most frequently in those who are habitual users of alcoholic beverages in moderate amounts. Ale, beer, and the sweet and the heavy wines are the beverages which are most apt to provoke the trouble. Of wines, the dry white wines and old Bordeaux have been found the least harmful. Although individuals vary in their susceptibility to the ill effects of alcoholic beverages, and although the different beverages vary in their potency to do harm, they should all be forbidden the gouty.

Patients who are gouty should drink water copiously in order that the kidneys may be made to act freely and that the waste matter may thus be washed out of the system. From five to eight glasses of good pure water should be drunk daily.

Many spring waters have been recommended as preventives of gout. It is probable that large quantities of water do more good by the physical presence of fluid in the blood-vessels and tissues than the various mineral ingredients which spring water may from time to time contain. There are three varieties of spring waters especially recommended for gout: First, those which are particularly pure and contain a minimum amount of mineral matter. Without doubt, their effect is a physical one. Second, the alkaline waters of which Vichy is a type. Alkalies well diluted, introduced into the blood, do seem to stimulate normal nutritive changes in the tissues of the body. The alkaline waters also have a beneficial effect upon the contents of the stomach, which are usually acid because of abnormal fermentation. Third, spring waters which contain iron, arsenic, and lithium. They are useful, especially the arsenical waters, for those gouty persons who have affections of the skin and bronchial mucous membranes. Many of the cases of gouty dyspepsia are helped by these waters. Royat, in France, may be regarded as a type of this group of mineral waters.

Spring waters rich in sodium salts are not beneficial for the gouty, as these salts in unusual quantities in the blood hasten the precipitation of insoluble urates in joints or other tissues.

Hot mineral springs are resorted to by many who have chronic gout, for the purpose of bathing. Acute attacks are not benefited, but partially immobile joints with muscular atrophy are benefited. If patients have high arterial tension or hypertrophied hearts hot baths must be avoided.

Exercise is essential in order to prevent gout and to avert repeated attacks in those who are prone to it. The amount of exercise required must be determined by each person. As a rule it must insure several hours of outdoor life each day and for at least a few minutes daily must be violent enough to provoke sweating. When repeated attacks have stiffened the joints and enfeebled patients, it must be more gentle. Walking, bicycling, horseback-riding are the best. These more gentle means of exercise can often be supplemented with benefit by daily or frequent massage. Of sports golf, which insures mild exercise for several hours out-of-doors, is the best. The more violent games are rarely adapted to the gouty who are in middle life or have passed it.

Sufficient exercise should be taken daily, for the results thus obtained cannot be stored up at one time for future use.

In acute attacks physicians still resort, as Cullen recommended them to do, "to patience and flannels." Abortive treatment cannot be recommended. It has been attempted by strapping tightly the affected joint, applying ice to it, administering large doses of colchicum and sometimes morphine. Attacks have undoubtedly been stopped short in this way, but very dangerous symptoms have also followed the treatment, such as fainting and disorders of the heart. Most frequently soothing applications are made to the diseased joint, such as chloroform liniment or menthol (8 gm.) in camphorated soap liniment (120 c.c.), or in an oil composed of Guaiacol 25 c.c., Ol. gaultheriæ, 25 c.c., and Ol. olivæ, 50 c.c. Pomades with cacao butter and olive oil as bases are often used. To them may be added morphine, cocaine, belladonna, menthol, guaiacol, and other local anæsthetics and analgesics.

After each local application has been made the affected foot or joint is wrapped thickly in flannel to protect it from cold and to promote local sweating. Rendu ("Traité de Therapeutique Appliqué," 1895, Paris) advises wet bandages which are gradually made colder until the diseased part is accustomed to ice-cold applications. The cold benumbs the sensibility, lessens pains and swelling, and shortens the duration of the malady. Like the so-called abortive treatment it must be used with care.

Blood-letting and blisters are no longer used in gout, but purgatives are. Calomel and jalap constitute a favorite prescription of English physicians. Certainly at the onset of an attack it is important to empty the gastro-intestinal tract. A full dose of calomel followed in a few hours by a saline (the liquid citrate of magnesia is particularly eligible) does much good. At the same time the patient should abstain from food for from twenty-four to forty-eight hours but should drink water freely. When food is administered, and this should not be until copious bowel movements have insured the emptiness of the intestines, milk should be given.

Of medicine colchicum is chiefly relied upon to relieve the acute symptoms. Twenty to twenty-five minims of the wine of colchicum root may be given three or four times daily. Instead of this preparation the tincture of the seeds of colchicum may be used. As soon as the sedative effects of the drug are obtained it should be given in smaller quantities and often can be discontinued. If used too long it will provoke nausea and excessive diarrhœa. Indeed, a peculiar susceptibility to these effects of the drug makes its employment impossible in certain cases. Colchicum probably produces its good results by its sedative action upon the nervous and cardio-vascular systems and by helping elimination by its purgative properties.

Next to colchicum the salicylates are found useful. The salicylate of sodium is most used, but by some physicians the salicylate of lithium is preferred. A combination of the salicylate of sodium and bromide of lithium has proved useful to my patients. The salicylates are less certain in their effect than colchicum, but especially useful after colchicum is discontinued and in prolonged subacute attacks.

Alkalies are also used commonly. The best are the potassium and lithium salts. They are usually combined with colchicum or the salicylates. Originally they were given to hasten the elimination of uric acid by making soluble salts of it. Numerous other drugs in recent years have been tried for the same purpose, such as piperazin, lycetol, and lysidin. The doubt which prevails to-day in the minds of pathologists in regard to the pathogenic properties of uric acid makes their employment theoretically less urgent. Lithium has been shown to be useless so far as increasing the solubility of urates in the blood is concerned, for when administered by the mouth it forms insoluble compounds in the stomach and does not unite with the uric acid. However, I am convinced that lithium salts are beneficial in the indigestion of the gouty, probably because they unite with constituents of the contents of the stomach, lessen their acidity and toxicity.

Guaiac is another remedy which is often employed in gout with benefit. Its mode of action cannot be satisfactorily explained. It proves most useful in subacute or mild acute cases.

Chronic gout must be treated hygienically for the most part and acute exacerbations must be treated as acute gout is. The salicylates and alkalies are especially useful in these cases. Piperazin and similar drugs have been much used of late years to dissolve tophi. The clinical results of their employment as they are described in periodical literature are conflicting. It and lysidin are also credited with the relief of pain. Massage can be employed in chronic gout, and often after acute attacks, with benefit. It must, however, be applied with gentleness. It helps to reduce swelling, to make the joints more supple, and to strengthen the unused muscles. When joints are permanently deformed it is necessary by massage, electricity, and hydrotherapy to keep the atrophying muscles strong, in order that as much usefulness as possible may be preserved to the diseased part.

Little can be done to remove uratic deposits. Most attempts by local treatment are found to be more harmful than useful. Surgical interference is not to be recommended unless suppuration occurs near them (and it is a rare complication, not a part of the disease) or sloughing of the skin over them takes place; then the pus should be evacuated and any exposed urates scraped out and the wound treated as any other sluggish and infected wound would be.

A residence in a mild genial climate where an outdoor life can be had continuously is of great advantage in checking the progress of this ailment.

Often diet must be still further modified because of arteriosclerosis or contracted kidney and albuminuria. It must then be made even simpler. Red meats should not be used or, if at all, rarely. Indigestion and constipation must be carefully corrected or guarded against. Great pains must be taken to prevent fermentation in the gastro-intestinal tract.

The iodides are frequently needed to lessen arterial tension. They may have to be given for weeks at a time. Potassium iodide is chiefly used, but Bouchard and Dyce Duckworth recommend the iodide of lithium. Nitroglycerin is sometimes needed for its temporary but more pronounced effects upon the arteries.

In irregular gout chief reliance must be placed upon hygienic treatment. Various symptoms of the malady may for a time need medical treatment addressed to meet them. For instance, in the eczema of the gouty local applications are of benefit; but an abstemious, carefully regulated diet, the copious drinking of water, the maintenance of good elimination by the bowels, kidneys, and skin, and suitable exercise, are essential to success.

For the headaches and neuralgias much can be done with the compounds of salicylic acid, phenacetin, antifebrin, and similar drugs, but the relief is imperfect or transitory unless a suitable regimen is prescribed and maintained. Hemicrania can frequently be averted, when the temporal arteries begin to be tense and twinges of pain give warning of an attack, by a full dose of citrate of magnesia.

Often such patients must change their business in order to obtain permanent relief, thereby avoiding the anxiety and confinement which a commercial or professional life necessitates. *N. S. Davis, Jr.*

GOWERS' TOXIC PARAPLEGIA. See *Spinal Cord Diseases: Combined Scleroses.*

GRAMINEÆ.—(The Grass Family.) This is doubtless, all things considered, the most important family of plants. The bamboos contribute most important building and structural material in the tropics, as well as considerable fibre material, which latter is also contributed by many other grasses. The uses of straw in this connection are too well known to require description. The grasses contribute by far the most important stock fodders, while the cereals constitute the most important part of human food and the principal source of alcoholic beverages and of alcohol itself. The sugar-cane, as well as sorghum, is a grass. An important fixed oil is obtained from Indian corn, which is also the chief source of glucose, and the importance of the starch yielded by it, as well as of those obtained from wheat, rye, rice, and barley, is apparent. Several important volatile oils are yielded by species of *Andropogon.* With one or two unimportant exceptions, poisonous properties are unknown in the family. Very few of the species are of distinct medicinal use, though Triticum is official, and ergot proceeds indirectly from rye. *Henry H. Rusby.*

GRANATUM. See *Pomegranate.*

GRAND HAVEN MINERAL SPRING.—Ottawa County, Michigan.

Post-Office.—Grand Haven. This is the terminal station, on Lake Michigan, of the Detroit, Grand Haven and Milwaukee Railroad. It can also be reached from Chicago by lake steamer. The location is a cool and pleasant place in summer, and excellent opportunities are afforded for surf bathing in the lake. According to an analysis by C. G. Wheeler, the water is composed as follows:

One United States Gallon Contains:

Solids.	Grains.
Sodium carbonate	2.09
Potassium carbonate	2.74
Calcium carbonate	2.01
Magnesium carbonate	1.52
Iron carbonate	.08
Sodium sulphate	71.29
Sodium chloride	306.03
Potassium chloride	1.93
Calcium chloride	148.05
Magnesium chloride	71.53
Magnesium iodide	.05
Magnesium bromide	.17
Calcium fluoride	.05
Alumina	.30
Silica	1.05
Total	608.89

This water contains sufficient sulphate of sodium to give it great efficacy in cases of engorgement of the liver, abdominal plethora, and dyspepsia associated with these conditions. *James K. Crook.*

GRANULATION TISSUE.—Definition.—In crushing injuries, wounds involving the loss of considerable tissue, neglected wounds or those infected with pathogenic bacteria, or in wounds in which close coaptation by sutures is impossible, the healing process takes place by secondary intention, or, it is said, healing occurs by granulation. The origin of the latter expression is traceable to the appearance in such injured parts of minute pink or rosy elevations, the granulations; such surfaces are said to be granulating and the tissue forming the tiny nodules, as well as that below and about them, is granulation tissue. Granulations are peculiarly limited to exposed situations; similar processes of healing upon other surfaces, such as the intestinal canal and serous membranes, are very rarely if ever marked by elevations comparable to the granulations of healing wounds. This term consequently had its birth in the outward objective features of healing injuries of various sorts as well as locations. Granulations are described, in the older works of surgery and pathology, as arising from the sectioned ends of bones, in abscesses undergoing "self-purification," chronic ulcers, fistulous openings, etc. The essential requisite seems to have been that they should occur either where they would be plainly visible or easily demonstrable or in such hidden locations where previous experience had proven their development. Necessarily this conception of granulation tissue was from the clinical viewpoint almost exclusively.

With the fuller knowledge of the process of inflammation, and especially of the regenerative changes connected with resolution, the designation granulation tissue has invaded topics of a more general character than those connected simply with surgical pathology. This tendency is, without doubt, due to the selection, by writers, of wound healing by secondary intention, as the type of regeneration or resolution in the inflammatory process; and because the cellular changes in resolution have more or less in common, no matter what the location is. The term granulation tissue has, therefore, by degrees acquired the significance of embryonal tissue. From this pathological conception, the chronic processes of inflammation, tuberculosis, syphilis, actinomycosis, leprosy, etc., in which proliferative changes predominate, acquired the group-name granulomata. There may be no granulations in the surgical sense in a gumma or actinomycotic growth, yet they are commonly described as made up of granulation tissue. The analogy between the granulation tissue of a healing wound and a deeply seated chronic inflammation such as a gumma of the liver or testicle, is a histologic one; the former possesses perceptible granulations, the latter a structure similar to such delicate and sometimes barely visible excrescences. Granulations do not, as a rule, develop in the granulomata, but they are obvious characteristics of all sorts of wounds.

That consideration of granulation tissue which maintains its parity to embryonal tissue and its inflammatory origin belongs to the general subject of inflammation (see *Inflammation*), whereas the following description deals solely with granulation tissue as it is met with clinically, with the structures that gained the name primarily.

Healthy Granulations. — The surface of open wounds after a few hours becomes covered over with a delicate pellucid, gray or whitish layer which slowly becomes thicker and finally resembles the buffy coat. Its formation takes place after the cessation of hemorrhage, although some clear or slightly blood-tinged fluid may ooze from spots on its surface or from the edges for some time. Exposure to the drying influences of the air causes this exudate to change into a compact, rather brittle crust that effectually protects the underlying tissue; it is often some shade of brown from the admixture of blood. The protection of wounds by dressings may lessen the formation of a crust and the fibrinous coating may remain thin and translucent. For a number of days there may be no change in the appearance of such defensive vestures. After a variable length of time, depending upon the anatomical location, the variety of tissue, the individual's age, and other factors, granulations arise. It is usually a number of days, from four to ten, before they attain macroscopic proportions.

When it was regarded as good surgical treatment to approximate the edges of the flaps with strips of adhesive, after amputation of an extremity, it was observed that granulations appeared earliest on the vascular soft parts and sooner on the sectioned cancellous than compact bone. If, after a certain period of repose, the dried blood clot of the exposed wound or the dressing of the more carefully protected wound be removed, minute pink points will be visible upon the paler tissue around. They mark the site of future granulations, whose development is easily followed by examination at intervals. The pink spots deepen in hue and others appear; they enlarge to blotches that have a bright ruddy aspect, and become elevated as small globular tuberosities. In *sensu strictu*, this is granulation tissue.

These small eminences vary in size and give the surface a decided granular appearance; they level the smaller irregularities of rough and lacerated injuries. The tissue that forms them is common to all chronic inflammations; it is embryonal tissue in process of cicatrix production. The elevations containing loops of newly proliferated blood-vessels have been explained by Hamilton upon the basis of lessened pressure; in this manner he would account for their absence in deeply seated morbid conditions. It is doubtful if altered conditions of pressure are the only agencies influencing their development.

Perfectly healthy granulations may vary in height and form, they may possess flat or rounded tops and a uniformity or irregularity in size may be observed. Double or compound granulations are described. Their consistence varies within narrow limits; possessed of broad bases these warty growths give the impression of firmly interwoven tissue with soft but not fluid contents. On removal of the covering exudate by gentle washing, a clean, moist or glazed surface, translucent and devoid of visible vessels is exposed. Although there is no distinctive color to healthy granulations, the more livid hues bespeak poor circulatory conditions. A faint pellicle with bluish zones that merge into the white of the adjacent skin marks the healing margins from which epithelization has already begun. Healthy granulations are extremely sensitive if they arise in tissues well supplied with nerves; others from such structures as compact bone and tendons have no sensibility. When situated on a flat surface they seldom rise much above the level of the adjacent skin. The cells composing granulation tissue are those peculiar to chronic inflammation; however, in the average granulating wound there are probably a greater variety than in the usual deeply seated chronic inflammation. Our knowledge of the histology and histogenesis of the healing process is in the main derived from experimental work upon animals, nevertheless it is generally accepted that healthy human granulations may contain all varieties of leucocytes and all forms of fibre-producing cells; also red blood corpuscles, phagocytes, giant cells, budding blood-vessels, fibrin, bacteria, and an intercellular substance of altered fluid from the blood and lymph vessels.

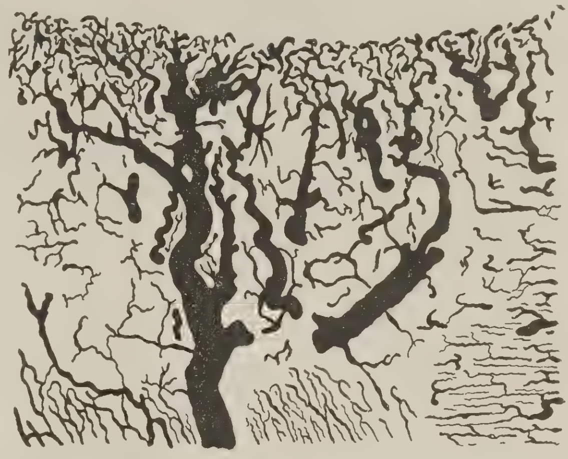

Fig. 2347.—Injected Blood-Vessels in the Granulation Tissue from an Experimental Injury of the Tongue of a Dog. The arteries have a greater tortuosity. Six days after injury. (Modified from Thoma.)

Pathological Granulations.—The extent to which, in a specific example, the exudative and retrogressive or degenerative changes exceed those of proliferation, depends upon many factors; chief among these are the stage of healing and the initial cause. It has long been recognized by surgeons that variations may occur in the general mode of healing, deviations from the normal that permit the use of such a pleonastic expression as pathological granulations. The luxuriant or exuberant granulations have been known by the laity immemorially as "proud flesh" and as altogether undesirable in a healing wound. The torpid or languid granulations and the spongy or fungous forms may so delay healing that there is an easy transition from granulation tissue to ulcers. Ulcers consist of granulation tissue when the macroscopic evidences of proliferation attain the degree of distinct granulations; other ulcers, the seat of extensive necrosis and exudation, may not possess any proliferating tissue; such ulcers are not granulating. Over forty years ago Paget made the statement that "all the varieties in the aspect of granulating wounds and sores, which the practised eye can recognize as signs of deflection from the right way to healing, are so many instances of different diseases of the granulation substance, diseases not enough investigated, though of much interest in the study of both the healing process and the organization of new products in inflammation."

This complaint finds an echo in the claim made by Reinbach, who, in an article recently published, states that he was unable to find in the literature at his command a single instance of researches of this character, and he adds that Ziegler also knew of none. Reinbach prefers to abandon the older nomenclature comprising such terms as fungous, spongy, erethistic, croupous, etc., for the general term pathological granulations.

Of these he recognizes two forms with several subordinate types: (1) The *luxuriant superficial granulation*, that is usually "self-purifying" and characteristic of acute processes, and (2) the *superficial chronic granulation*. The strictly torpid granulations he classifies with ulcers on account of the absence of formative tissue. As for the first form they are marked by the histologic features that belong to the process of suppuration (see *Inflammation*). Quantities of bacteria occur—generally cocci that show no special arrangement—and at different levels the changes indicative of miliary or microscopic abscesses. Leucocytes swarm within such granulations, and among them eosinophiles and mononuclear leucocytes are numerous. The capillary loops of the outer zones suffer some necrosis. In spite of the exudative and destructive changes karyokinetic figures are numerous in the deeper portions in fibroblasts and endothelial cells, and the fibroblasts produce fibres and become connected in the usual way.

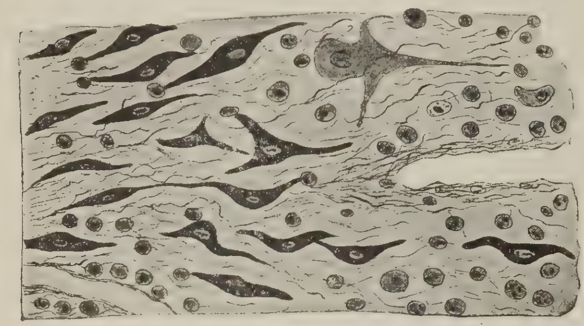

FIG. 2348.—Organizing Granulation Tissue. The left edge represents the deeper part. The round cells are both mono- and polymorphonuclear leucocytes. There are many spindle-shaped fibroblasts. (Modified from Ribbert.)

As examples of superficial chronic granulations, Reinbach mentions both the torpid granulations, which, however, show some signs of growth, and those covered with mottled and white patches caused by necrosis of the outermost parts. The first of these subdivisions, although very slow to heal, nevertheless contain vertical bands of fibre-forming cells. They often follow burns and constitute virtually lesions intermediate between granulation tissue and real ulcers. The second variety, covered by a fibrinous exudate in spots and by necrotic tissue, was described by Billroth as "croup of the granulations." Surgeons on meeting with these hindrances to the normal course of healing are inclined to suspect wound diphtheria, *i.e.*, a true infection with the bacillus of diphtheria. However, such areas of necrosis superficially located upon otherwise healthy granulations may be caused by other non-pyogenic bacteria, for example, the Bacillus coli.

The fibrin upon these diseased granulations, commonly limited to the periphery, may extend to considerable depths; when the spots clinically are dark yellow and brown, the necrosis may be accompanied by practically no inflammatory changes.

A careful review of the work of Reinbach demonstrates quite clearly that the interferences with the process of cicatrization in granulation tissue are due to the precipitation of fibrin either as a covering or among the cells, to simple necrosis, or to that form of necrosis which with serous exudation or liquefaction is generally known as suppuration. His work is based upon the careful histologic examination of tissue removed from many conditions that were associated with granulating surfaces. There is urgent need of equally thorough bacteriologic examination of such diseased human granulation tissue, especially researches that would include the use of animals.

There is yet another fact that prevents normal cicatrization, and that is obstruction to the blood supply of the growing tissue. The obstruction is only partial, and without doubt in many instances is attributable to an arterial supply that is inadequate in the number of vessels or their total calibre. In other cases the action of morbid conditions more centrally located or dependency of the part leads to inefficient supply of blood. That an œdema of granulation tissue may occur is well known; doubtless a deficiency in quality or quantity of nourishment is responsible for the occasional total failure of resolution. Briefly, granulation tissue may be the seat of extensive necrosis, œdema, and suppurative or fibrinous inflammations as well as combinations of these processes. Other pathological conditions, such as hemorrhage and the various cellular degenerations, may arise, but generally only as minor and incidental changes. The causes of pathological granulations often are to be sought in the character of the primary lesion, rather than in secondary infection or the injury of healthy granulations. Infection at the time of injury is frequently responsible for subsequent difficulties in healing.

THE PROTECTIVE QUALITIES OF GRANULATION TISSUE.—It is well known that granulations bleed readily; slight trauma of any sort disturbs the unorganized tissue and lacerates the embryonal and sprouting capillaries. As for infection, many experiments have proven that in this respect granulation tissue constitutes a serviceable barrier. One of these was the now classical experiment of Billroth. He ascertained that no ill effects followed daily dressing of healthy and experimentally produced granulations of a dog's back with lint saturated with pus, whereas inoculating such animals with the same material caused death. This simple test was many years later followed by the extensive experimental study of Afanassieff, who in a more scientific manner and by exact bacteriologic technique verified the results of Billroth.

Granulations were produced upon many animals of different species, and upon them virulent cultures of such bacteria as the bacillus of anthrax and the vibrio Metschnikovi were carefully smeared with a thick platinum needle. The serum exuding from granulations so treated was examined from time to time, stained preparations and media inoculations being made also; the virulence of the resulting growths was examined; histologic examination of the granulation tissue for bacteria and the inflammatory changes was carried out, and animals were killed in order to ascertain if general infection had occurred. Ample control experiments were employed.

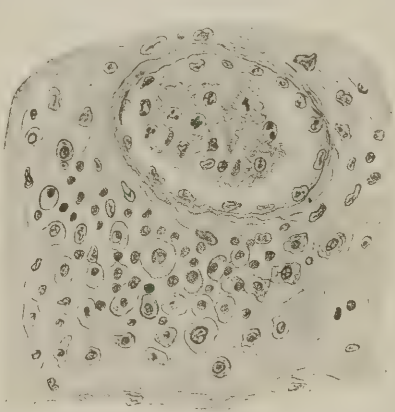

FIG. 2349.—Perivascular Collection of Round Cells or So-called Lymphoid Tissue. They contain various forms of leucocytes, and as the inflammation becomes chronic, plasma cells occur in such cell accumulations. (Modified from Ribbert.)

He found that bacteria placed upon healthy granulations of animals did not penetrate, nor did general infection result. Inoculations made with recovered growths of the bacteria denoted an attenuation in virulence by the sojourn upon granulation tissue. Afanassieff was strongly inclined to look upon the protection afforded by the granulation tissue in the light of a vaccination. Such an explanation, however, is controverted by two facts. One of these is that local reactions in the granulation tissue were not observed with sufficient regularity in all animals to be in accord with the production of a bacterial immunity. Another fact is that Noetzel has repeated many of the experiments of Afanassieff and found that after bacteria were kept in contact with granulating wounds for many days the animals did not acquire any immunity.

It must be remembered that in granulation tissue mechanical obstacles exist to infection, such as the outward current of fluid from the vessels and the exceedingly slow circulation. Phagocytosis undoubtedly plays some part, although it may be that the ingested bacteria are no longer viable at the time of their incorporation. The extracellular destruction of the bacteria by the fluids present in granulation tissue (Afanassieff) or by enzymes, belongs to fundamental problems of immunity (see *Immunity*).

One cannot overlook the fact that when granulation tissue has formed, a defensive mechanism has been produced and its production is in response to external injury. But granulation tissue usually contains bacteria; especially frequent are the ordinary pyogenic forms.

Although resistant to bacterial infection, granulating wounds allow of the ready absorption of many soluble substances. Roux, Bonnet, Demarquay, Gorny, Maas, and Hack, and many others, have made experiments regarding this. Not all substances are absorbed with equal facility. The concentration of the solution, its chemical composition, the size of the granulating surface, and the character of the injury producing it, as well as the time contact is allowed, all influence the absorption. Granulating surfaces following burns and caustics are not so permeable as some others; absorption is more rapid from some healing wounds than from freshly cut surfaces. Apomorphine and curare are not readily absorbed, but carbolic acid diffuses with great facility. Various alkaloids such as strychnine, morphine, pilocarpine, cocaine, etc., have been used, and carmine, sodium sulpho-indigotate, iodoform, potassium iodide, sodium salicylate, as well as many other substances. Hack recovered ferrocyanide of potassium from the urine ten minutes after its application to a granulating surface, and Maas was able by spraying abscess cavities with a camphor solution, in a patient with vertebral caries and pyæmia, to sustain the heart action sufficiently to allow operation. These and many other interesting and curious facts have been discovered about this phase of granulation tissue.

Cicatrization.—With healing of wounds by granulation a scar is formed that becomes paler as contraction takes place. Resolution in this form of inflammation is not marked by any peculiarities that distinguish it from cicatrization elsewhere. It is, however, customary to refer in this connection to the very deforming contractions that sometimes follow burns, but it is the location of the cicatrix rather than any special properties it possesses that marks it as singular. The loose subcutaneous adipose and areolar tissues allow scars to produce disfigurements that excite special interest on account of their exteriority. Similar malformations may occur in less exposed locations that are fully as interesting and as remarkable—for instance, the acquired dextrocardia and lesser dislocations of the heart that follow indurative processes of the neighboring viscera. They constitute excellent examples of the partial failure of inflammation as an adaptive process. The development of keloids in scars might be cited as another instance in which abnormal resolution builds a growth, which, to the surgeon at least, must ever serve as a striking illustration of the failure of inflammation as an adaptive process. In contrast to these irregularities in resolution and fully as interesting is the failure of granulation tissue to organize about certain fistulous passages and their openings that lead to foreign bodies, necrotic tissue, etc. These are the so-called "sequestrum granulations." The failure of cicatrization in these cases seems to indicate a better adaptation of the process of inflammation, as it occurs in granulation tissue, to meet the requirements.

E. R. Le Count.

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GRAPE.—(Including *Raisin*, or *Uva Passa.*) The genus *Vitis* Tourn. (fam. *Vitaceæ*) comprises about thirty species of Vine, a number of which, either in their improved forms, or as hybrids, contribute our grapes. The young leaves, tendrils, and green fruit of the vine are sour and astringent, containing *tartaric, malic,* and other fruit *acids* or their salts; *tannic acid, quercetin, quercitrin,* etc., sugar, gum, and several earthy and alkaline bases. They are more or less employed in Europe in the form of "teas" or syrups as domestic remedies. The juice of one particularly sour variety expressed from the green fruit, and known as *verjus,* is used to make a flavoring and refreshing syrup. The sap of the stems has also been employed. Ripe grapes, and especially raisins, are much sweeter, containing from ten to forty per cent. of *sugars* (*dextrose, levulose, inosite*) besides the acids, salts, etc., above mentioned. Still these are more or less employed for the same purposes as the herbage. Their medicinal virtues are very unimportant.

From the ripe fruit of the European Vine, *Vitis vinifera* L., raisins, and from one of its varieties the Greek, Zante or English "currants" are made merely by careful drying. Raisins are slightly laxative, like figs and other dried sweet fruits, and they have a peculiar power in imparting flavor. *Henry H. Rusby.*

GRASSE, FRANCE, a town of 15,000 inhabitants, is eleven miles north of Cannes, from which it is reached by railway in forty minutes, and also by direct railway from Nice. This resort of the Riviera was brought especially to public notice by the visit of the Queen of England in the spring of 1891. It is very picturesquely situated, high above the hillsides, and is well sheltered from the cold winds on the north. It has an elevation of 1,070 feet, and possesses a very mild and salubrious climate, essentially the same as that of Cannes, with the exception that it is less stimulating than a resort directly upon the seashore.

The temperature is a little lower in winter than that at Cannes, on account of the elevation; the mean temperature of the year being 60.2° and for the winter 46.4°, while that at Cannes is 60° and 47.75° F. respectively. "Grasse," say Weber and Foster (Albutt's "System of Medicine," 1896), "forms a useful intermediate station during April and May for patients who find the heat in those months already too oppressive at Cannes."

For the climatic detail one is referred to the articles upon Cannes and Nice. In brief, Grasse affords a favorable winter resort for invalids unable to remain near the sea. Grasse possesses a luxuriant vegetation and is celebrated for the cultivation of flowers and the manufacture of perfume, which is the most extensive in France, if not in the world. The air is heavy with the scent of flowers, which with some invalids is said to produce an exaggerated form of hay fever. Great fields of orange blossoms, heliotrope, hyacinthe, roses, violets, jonquils, geranium, and other flowers are cultivated about Cannes and Grasse; 60,000 acres being devoted to this industry, yielding annually 2,200,000 pounds of roses and 4,000,000 pounds of orange flowers.

At the foot of the village are great plains of olive trees. The views are very beautiful and extensive, and the excursions round about are many and attractive. The town itself is not particularly attractive, but this is compensated for by its picturesque situation and beautiful views.

The water supply is good, but the sanitary condition was said by Linn ("Health Resorts of Europe"), in 1893, to be far from perfect. The accommodations are good but apparently limited.

The climate is said to be beneficial to sufferers from asthma, gout, nervous affections, insomnia, neuralgia, and rheumatism. *Edward O. Otis.*

GRAVEL. See *Kidney Diseases.*

GRAVES' DISEASE. See the APPENDIX.

GREAT BEAR SPRING.—Oswego County, New York. This spring is located near Fulton. It has been known for many years, having been used by the aborigines. Within the last few years the spring has been improved and the water has an extensive sale in Syracuse. More recently it has been introduced into New York and other large cities. The water is but feebly mineralized, but it is remarkably pure, and its freedom from organic matter gives it excellent qualities for the table. Its very small cost is an additional advantage. The following analysis was made in 1890 by Dr. William Manlius Smith, of Syracuse:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Calcium sulphate	0.72
Calcium carbonate	3.50
Magnesium carbonate	1.25
Magnesium chloride	.47
Sodium and potassium carbonates	Traces.
Total	5.94

James K. Crook.

GREEN LAWN SPRING. Jefferson County, Illinois.

POST-OFFICE.—Mt. Vernon. Hotels and boarding-houses. These springs are located in the city of Mt. Vernon, 76 miles east of St. Louis. This point is reached by the Louisville, Evansville and St. Louis, by the Jacksonville and Southeastern, and by the Louisville and Nashville railroads. The springs are six in number, and are surrounded by a park of about eight acres in extent in the centre of the city. Their waters are discharged from a vertical stratum of slate about eight inches in width and bisecting a horizontal stratum of slate of between two and three feet in thickness. They belong to the class known as saline-chalybeate waters, each spring differing somewhat in properties from its fellow. The one most used, known as the "Washington" Spring, contains the carbonates of lime, iron, and magnesia, bicarbonate of sodium and potassium, and chloride of sodium, with traces of iodine and bromide. Free sulphurous acid is present in considerable quantities, and the water is quite heavily charged with carbonic acid gas. The temperature of all the springs, with one exception, is about 56° F. In this single exceptional case, in which the temperature ranges about 10° higher, the waters are used for bathing purposes in rheumatism, with good results. A peculiarity of the Washington or main spring is its eccentric behavior, which seldom fails about the time of the autumnal equinox. It is said that the waters always become turbid at these periods and the same disturbances have been observed after great storms or earthquakes, even though these events occur in regions remote from the springs. The waters are said to remain red with an excess of iron for a short time after these disturbances and then to become harsh and acrid from an excess of alkaline ingredients. The country surrounding Mount Vernon is about equally divided between prairie and timber, a considerable portion of the latter being found on elevated ridges. On the north a belt of timber, about ten miles in depth, affords protection against the winds of winter and causes a considerable modification of temperature. The waters of the main springs are very efficacious in the treatment of dyspepsia, torpid liver, biliousness, and other disorders of the chylopoietic organs. *James K. Crook.*

GREENBRIER WHITE SULPHUR SPRINGS.—Greenbrier County, West Virginia.

POST-OFFICE.—White Sulphur Springs. Hotel and cottages.

ACCESS.—Viâ main line of the Chesapeake and Ohio Railroad direct to Springs. This celebrated summer watering-place is located on the western slope of the Appalachian Mountains, at an elevation above tide-water of more than 2,000 feet. The situation is well within the famous spring region. Within a radius of thirty miles are the Rockbridge Alum, the Hot, the Warm, the Healing, the Sweet, and other well-known springs, while the Natural Bridge, Millboro, the Alleghany, and other resorts are near by. For many years past the Greenbrier White Sulphur Springs have been regarded as a representative summer resort of the South, and it has lost none of its ancient and well-deserved prestige by the development of other springs. As in ante-bellum days, here will still be found the best elements of the social life of the South, with a generous intermingling of Northern beauty and gallantry drawn thither by the numerous attractions of the place. The surrounding scenery typifies the picturesque beauty and grandeur of the Alleghanies. The visitor from the heated and dusty city is at once attracted by the vast lawn of green, velvety turf, shaded by noble forest oaks, luxuriant sugar maples, and venerable pines. Under these monarchs of the forest wild flowers are seen in profusion and in great variety. Among the surrounding mountains are "Kate's" and "Greener," each a mile distant and reaching an altitude of 3,500 feet, and the mountains known as "White Rock," three miles distant, the summits of which form a figure of gigantic size, known as the old "Titan," which, in solitary grandeur, keeps guard like a giant over the White Sulphur. What has been said of other Alleghany resorts applies in full measure to this. The mean annual temperature from April 15th to November 15th is about 63° F., or about the same as the mean annual temperature of Naples, Nice, and the Madeira. The atmosphere is salubrious and invigorating, and at no time excessively warm. The Grand Hotel, with its one hundred cottages, gives accommodation to an immense number of visitors. There are two important springs here, viz., the famous old "White Sulphur," and the "Chalybeate." The Sulphur Spring yields 1,800 gallons of water per hour, and this amount does not vary even during the longest spells of wet or dry weather. It has a uniform temperature of 60° F. An analysis by Prof. A. A. Hayes, of Boston, shows the following mineral contents:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Calcium carbonate	7.07
Magnesium sulphate	35.42
Calcium sulphate	78.35
Silicates	3.46
Magnesium chloride	1.00
Organic matter	4.36
Total	129.66

Gases.	Cubic Inches.
Carbonic acid	11.28
Sulphureted hydrogen	.24
Oxygen	.48
Nitrogen	4.64
Total	16.64

This analysis was made many years ago (1842), and a newer and further analysis is desirable. The water acts on the kidneys, bowels, liver, and skin. As a diuretic its effects are very soon apparent; but some days are usually required before it produces a decided action on the bowels. Its operation on the liver, too, may not be manifest for some time, and when there is much sluggishness of this organ some auxiliary medication is required. Its effect upon the skin is very apparent, though not immediate. The analysis does not fully explain another important action of the water, an effect which has been attested to by several generations of qualified medical men. This is its alterative power, or that peculiar influence by which it effects a salutary alteration in the blood, in the various secretions, and upon the numerous tissues of the body. No general directions can be given for the internal use of the water. The hours, the quantity, and the period for which the water should be drunk depend upon the individual requirements of the case, and should be ascertained by consulting a physician experienced in the use of such waters. Combined with the influence of the favorable surroundings, the use of the water often proves curative in obstinate cases of chronic bronchitis, in hay fever, in bronchial asthma, and in nasal catarrh. Conjoined with the use of the hot sulphur baths it is of decided value in rheumatism and gout, and is an efficacious adjuvant in the treatment of tertiary syphilis, chronic metallic poisoning, and dartrous skin diseases. According to Dr. Moorman, for many years the resident physician, the water is contraindicated in organic heart disease, carcinoma of the stomach, and phthisis pulmonalis. The water never proves beneficial when it persistently excites the frequency of the pulse. The water used for bathing flows from the sulphur spring. The bathing establishment has recently been greatly enlarged and remodelled, and it is now believed that it will prove in all respects satisfactory to those wishing to avail themselves of its use.

The Chalybeate Spring. About forty rods from the White Sulphur Spring is a chalybeate spring in which iron exists in the form of carbonates. For the last twenty years this water has been considerably used by a number of visitors who require a ferruginous tonic, and its effects have realized the early hopes that its discovery created. It has not been fully analyzed. *James K. Crook.*

GRINDELIA.—California Gum-weed. *Rosin-weed.* "The dried leaves and flowering tops of *Grindelia robusta* Nutt. and of *G. squarrosa* Nutt. (fam. *Compositæ*)" (U. S. P.). These are large and coarse, perennial, resinous herbs, of the far western and southwestern United States. The former was first introduced, then the latter, as possessing different properties. It being quickly determined that the properties were similar, they were united under one title. Nevertheless, many physicians prefer the *G. robusta.* It is much scarcer and more difficult to obtain, and the other is very commonly supplied, broken up or otherwise treated to make a distinction, when robusta is specifically called for. A good mark of distinction is given below. The following is the official description:

Leaves about 5 cm. (2 inches) or less long, varying from broadly spatulate or obovate to lanceolate, sessile or clasping, obtuse, more or less coarsely and sharply serrate, often spinosely toothed or even laciniate-pinnatifid, pale yellowish-green or yellow, very smooth, finely dotted, resinous, thick and brittle; heads many-flowered, the involucres of many series of imbricated scales with acute, spreading or recurved tips. The heads of *G. squarrosa* are mostly longer than broad, contracted-campanulate or conical-urceolate; those of *G. robusta* are broader than long, depressed-urceolate. Ray-florets deep-yellow, ligulate, pistillate; disc-florets yellow, tubular, perfect; pappus of two or three mostly unequal awns, about as long as the disc-florets; odor balsamic, slightly narcotic; taste resinous and gummy, pungently aromatic, somewhat bitter. The quality is roughly indicated by the amount of resinous matter exuded upon the surface.

Resin is the principal constituent. There are also a little volatile oil, wax, gum and tannin, together with a bitter glucoside, in small amount. Its uses are external and systemic. The fluid extract, if painted upon a surface poisoned by rhus and similar agents, is one of our best remedies. It forms a dry coating which excludes the irritating atmosphere and prevents the spread of the poisonous fat, probably also absorbing it into the resinous film. It is of some similar use for treating burns and as an injection for urethritis and vesical catarrh. Its internal action, as a sedative expectorant, is not so readily explained. It is largely used, by way of the stomach, in chronic and subacute bronchitis, in asthma, and in whooping-cough. It is mostly given in the form of the official fluid extract, in doses of 1 to 4 c.c. (fl. ʒ ¼ to i.).

Hysterionica or *Baylahuen*, the herb of *H. Baylahuen* (Gay) Baill. (*Haplopappus B.* Gay) is a Chilian drug, very closely related, botanically, chemically, and physiologically, to grindelia. It contains a large amount of a brown, odorous, somewhat acrid resin and an essential oil. It is considerably used at home as an anti-diarrhœal and anti-dysenteric, and was introduced to Europe and the United States about the year 1890. Repeated trials showed it to possess some value in ameliorating the diarrhœa of phthisis. At the same time, it was found to act as a sedative diuretic and not to produce gastric irritation. The fluid extract was given in ♏ x. doses every six hours, and the administration prolonged. The drug has not come into general use. *Henry H. Rusby.*

GRIPPE, THE.—See *Influenza.*

GROWTH.—This article is divided for convenience into four sections: I. Definition of growth. II. Growth as a function of cells and tissues. III. Human growth statistically considered. IV. The laws of mammalian growth.

I. Definition of Growth.—Definitions of growth are almost as numerous and various as the writers on the subject. Among these we may distinguish two principal points of view. According to one of these, growth is defined as increase of size or volume. From this point of view any increase of volume is growth no matter to what cause it may be due, and differentiation is regarded as an entirely distinct phenomenon which may or may not accompany growth.

From the other point of view the term growth implies in a general way an increase in the number or size, or in both, of the histological elements; and also, but more vaguely, implies that the elements advance, or at least remain stationary in the scale of organization. In other words, if the increase in volume be due to developmental processes, or if it be accompanied by progressive differentiation, it is growth. But if, on the other hand, increase of volume be due to the deposition of products of degeneration, as, for example, fat, it cannot properly be regarded as growth. This definition is not so definite as the first, which, therefore, should be preferred.

II. Growth as a Function of Cells and Tissues.—It is evident that the growth of an organism is the sum of the growths of its tissues, and the growth of the tissues depends on that of the cells; hence growth ultimately rests upon, first, the increase in size of single cells, and, second, the multiplication of cells. Owing to their peculiar mode of growth, the plants afford the best material for the study of the process in its simplest form. At the tip of each stem or rootlet there is a mass of cells in an embryonic condition, and during rapid growth these cells undergo frequent cell division. There is at the extreme tip a cell or a group of cells that always divide by a transverse partition into a distal and a proximal daughter cell or cells. The daughter cell at the tip, the distal one, remains in an embryonic condition and divides again in the same manner. In this way the proximal daughter cell becomes separated from the tip by the successive divisions of the apical cell or group of cells. If we follow one of the proximal cells through its life history, we shall see that it at first divides repeatedly, forming a group of small cells with dense protoplasm and thin cell walls. This is the period of most rapid multiplication. A little later the process of cell division becomes less frequent in this group, and the cells become larger and exhibit large vacuoles containing a clear watery fluid. This is the period of greatest growth. Finally, the cells cease both to multiply and to increase in size; and the cell walls become thickened and assume the character of the tissue to which these cells belong. This is the period of histological differentiation.

In the development of the plant cell, then, may be recognized three stages: (1) Multiplication, (2) growth, and (3) histological differentiation. These three stages are represented by three zones in root or stem. The zone of multiplication surrounds the tip and extends but a short distance from it. Here growth takes place but slowly, so that between one act of division and the next a cell may double in size. But the most rapid growth is in the next zone, where a cell may increase to several times its original size without undergoing division. Sachs studied the daily rate of growth of the root of a bean (Phaseolus). A disc 1 mm. long was carefully marked off just behind the tip and was then measured daily. The rate of growth was found to increase from a little over 1 mm. on the first day to a maximum of about 14 mm. on the seventh day. After that the rate decreased rapidly to about 2 mm. on the tenth day. Ciesielski observed the rate of growth of different areas in the roots of several leguminous plants. The rootlets were marked off in half millimetres and the amount of growth in each space was measured after twenty hours. It was found that there was practically no growth in the first millimetre. Beyond that the rate increased gradually to the third or fourth millimetre, reaching there in the different species a rate of 1.8 to 2.6 mm. in twenty hours, and then the rate decreased again until at a distance varying from 5 to 6.5 mm. from the tip growth in length was found to have ceased.

From an analysis made by Kraus upon hothouse plants of *Heterocentron roseum* it was found that the percentage of water in the tissues increases from 73 per cent. at the tip of the stem to 88 per cent. at the first internode, and reaches a maximum of 93 per cent. in the second internode. Farther along the stem there is a slight decrease, the amount being 92.7 per cent. in the fifth internode. In plants, then, it appears that the period of most rapid growth is also the period of most rapid absorption of water by the cells.

In animals we do not find this division into zones of growth, and there is, as a rule, no area of embryonic cells to furnish material for growth for an indefinite period. On the contrary, the extent of growth for each species is more or less strictly limited by conditions of which we know very little. In the period of cleavage of the egg and anatomical differentiation (see article *Differentiation*) the whole embryo is in the condition found at the tip of the stem of a plant. The cells are all small, rich in protoplasm, and undergo division frequently, while there is little or no growth of the embryo as a whole. Then comes the period of most rapid enlargement accompanied by an increase in the amount of water, and this is followed by the period of histological differentiation. The rate of growth per unit of body weight decreases gradually until the animal reaches the limit of its species.

This was brought out by Davenport (1875) in his researches upon the embryos of frogs, the results of which are given in the following table:

GROWTH OF FROG EMBRYOS.

Days after hatching.	Average weight in milligrams.	Weight of dry substance in milligrams.	Weight of water in milligrams.	Per cent. of water.	Average increase daily in per cent. of body weight.
1	1.83	0.80	1.03	56	
2	2.00	.83	1.17	59	9.7
5	3.43	.80	2.63	77	23.9
7	5.05	.54	4.51	89	23.8
9	10.40	.72	9.68	93	54.0
14	23.52	1.16	22.36	96	25.2
41	101.0	9.9	91.1	90	1.2
84	1,989.9	247.9	1,742.0	88	

The frog embryo takes no food for several days after hatching, so that there is a loss of dry substance until about the eighth day; and yet it is between the seventh and ninth day that there is the greatest daily increment per unit of body weight. As the percentage of dry substance increases the rate of growth becomes less. The time of most rapid growth is the time when the cells absorb water most rapidly.

Similar results were obtained by Fehling (1877) from the measurement and analysis of twenty-one fresh human embryos, as shown in the following table:

GROWTH OF HUMAN EMBRYOS.

Number.	Length centimetres.	Sex.	Age.	Weight.		Per cent. of water.
				Fresh grams.	Dry grams.	
1	2.5	F.	6th week	0.975	0.24	97.54
2	15.0	M.	4th month	36.5	3.0	91.79
3	13.5	M.	4th month	56.5	5.1	90.97
4	18.5	M.	5th month, 1st half.	95.5	8.9	90.7
5	18.5	M.	5th month, 1st half.	104.7	8.2	93.2
6	19.0	F.	5th month, 2d half.	156.8	14.6	90.7
7	21.5	M.	5th month, 2d half.	244.0	22.0	90.96
8	22.5	M.	5th month, 2d half.	235.0	24.0	89.81
9	23.0	F.	5th month, 2d half.	264.0	29.5	88.9
10	24.0	F.	5th month, 2d half.	299.0	32.8	89.3
11	26.0	M.	6th month	361.8	39.1	89.2
12	30.0	F.	6th month	575.0	79.5	86.4
13	33.5	M.	6th month	771.0	125.2	83.77
14	34.5	F.	7th month	910.0	159.0	82.6
15	34.0	M.	7th month	832.9	138.2	83.5
16	36.0	F.	7th month	836.0	136.5	83.9
17	35.0	M.	7th month	1,117.0	170.71	84.8
18	38.0	M.	8th month	928.0	159.5	82.9
19	53.5	M.	Term	3,284.0	855.52	74.1*
20	44.0	M.	9th month	1,760.6	456.1	74.7†
21	45.0	M.	9th month	1,495.7	391.2	73.9‡

* Still-birth. † Died in uterus.
‡ Premature birth; atrophic; died thirteen days later.

It will be noticed that the youngest embryo, in the sixth week, contains the largest proportion of water, 97.54 per cent. From that the proportion decreases to about 74 per cent. at the time of birth. These figures should be compared with the next table in which Fehling summarizes his results as to the increase of weights.

INCREASE OF WEIGHT OF HUMAN FŒTUS.

	Weight at beginning of period. Grams. *a.*	Absolute monthly growth. Grams. *b*	Relative monthly growth. $\frac{b}{a}$
Second month	1	3	3.0
Third month	4	16	4.0
Fourth month	20	100	5.0
Fifth month	120	165	1.29
Sixth month	285	350	1.22
Seventh month	635	585	.92
Eighth month	1,220	480	.39
Ninth month	1,700	540	.31
Tenth month	2,240	1,010	.45
Term	3,250		

The relative monthly growth is high in the second month and increases to a maximum in the fourth. After that there is a decrease, sudden at first, and then more gradual.

For comparison with the growth of the human embryo Fehling studied the growth of embryo rabbits. For this purpose he reckoned the age of the fœtus in periods of three days, each period being supposed to correspond to a month of human gestation. Two embryos, the largest and the smallest, were chosen from each litter for analysis. Some of his results are given in the following table:

WEIGHT OF RABBIT EMBRYOS.

Number.	Weight of mother.	Period.	WEIGHT OF FŒTUS IN GRAMS.		Per cent. of water.
			Fresh.	Dry.	
1	1,850	5	0.619	0.052	91.5
2	1,850	5	.663	.057	91.4
3	1,500–1,600	7	10.631	1.5	85.9
4	1,500–1,600	7	12.83	1.7	86.7
5	....	8	23.6	3.5	86.3
6	....	8	24.6	4.0	83.8
7	....	8	15.95	2.25	85.9
8	....	8	12.3	2.0	82.2
9	1,806	8	18.61	2.94	84.2
10	1,806	8	18.68	2.32	87.6
11	3,240	9	62.35	11.35	81.8
12	3,240	9	45.78	7.6	85.6
13	2,854	9	41.98	8.0	81.0
14	2,854	9	50.33	9.33	81.5
15	1,800	9	29.25	4.9	83.2
16	1,800	9	28.56	5.83	79.6
17	About 1,800	10	34.29	7.22	79.0
18	About 1,800	10	33.05	6.7	79.7
19	....	New-born	38.4	8.4	78.4
20	....	New-born	38.3	8.8	77.1
21	....	14 days.	179.5	43.8	75.6
22	....	14 days.	224.0	75.4	65.1

The weight of the mother has great influence on the weight of the fœtus, and is given for that reason in this table. This factor is of less importance in human statistics, where the range of variation is comparatively much restricted.

The table shows a gradual decrease in the percentage of water in the tissues of the fœtus, and this is associated, as in man, with a gradual decrease in the relative rate of growth as shown in the following table:

GROWTH OF RABBIT EMBRYOS.

Period	Weight at beginning of period. Grams. a	Absolute growth during period. Grams. b	Relative growth per period. $\frac{b}{a}$
5	0.619	5.557	8.97
6	6.176	5.558	.89
7	11.734	6.916	.59
8	18.65	10.258	.55
9	28.908	4.762	.16
10	33.67	4.68	.13
Term	38.35		

The figures for the sixth period in this table are somewhat doubtful, for there is nothing to show that they were obtained by actual observation.

Per period the relative growth of the rabbit embryo appears to be less than that of the human embryo, but the period in the former case is only one-tenth as long as in the latter. The relative daily growth of the two, as calculated by Fehling for each period, is as follows:

RELATIVE DAILY GROWTH OF FŒTUS.

Period.	Man.	Rabbit.	Period.	Man.	Rabbit.
2	0.1		7	0.032	0.197
3	.142		8	.014	.183
4	.178		9	.011	.054
5	.049	2.99	10	.015	.046
6	.044	.305			

The more rapid rate of relative daily growth observed in the rabbit is associated, according to Fehling, with a greater percentage of water in the tissues.

All these results tend to show that in both animals and plants the most rapid increase in weight in proportion to the weight of the body takes place at the time when the tissues are at their least density. As the solid constituents of cells increase the relative rate of growth decreases.

Little is known of the effects of external conditions upon the rate of growth of animals, but upon the growth of plants external conditions have been shown to have a very marked effect. For a full discussion of this subject the reader should consult Davenport's very excellent summary ("Experimental Morphology," vol. ii., 1899).

III. GROWTH OF MAN.—We know very little concerning the earlier period of the growth of man, since the growth of the fœtus and of the infant has been but little studied. We have numerous observations on the weight of the child at birth, and on the growth from the fifth to the twentieth year (during the school age); some on the growth up to twenty-five years, referring chiefly to the upper classes (college and university students), and valuable statistics of men in armies have been compiled. As regards the growth and size of man, American investigations easily lead, for the anthropometric work of Gould and Baxter, and the researches of Bowditch, on Boston school children, and of Porter on the school children of St. Louis, have never been approached in value. Peckham's work in Milwaukee is also excellent. Quetelet, the pioneer in this field, pursued an erroneous method, which led him to false conclusions, which are, nevertheless, still currently cited, especially in Europe.

We divide the subject as follows: 1 Growth of the fœtus; 2, weight of the new-born child; 3, growth of infants, 0 to 5 years; 5, growth of children; 6, size of adults.

1. *Growth of the Fœtus.*—The difficulty of determining the age of the human fœtus, and of obtaining specimens certainly fresh and normal, has prevented our having any very definite information on this subject. Preyer has compiled the following table of the length of the human embryo in centimetres:

Lunar month.	Toldt (200 obs.).	Hennig (100 obs.).	Hecker.
First	1.5 (1.3)	0.75	......
Second	3.5	4.0	......
Third	7.0	8.4	4 to 9
Fourth	12.0	16.2	10 to 17
Fifth	20.0	27.5	18 to 27
Sixth	30.0	35.25	28 to 34
Seventh	35.0	40.25	25 to 28
Eighth	40.0	44.3	39 to 41
Ninth	45.0	47.2	42 to 44
Tenth	50.0	(49.0)	45 to 47

If the absolute length at the end of each month is divided by the increase during that month we obtain what Preyer calls the relative growth. Hennig's figures give the following relative growth for each month: First, 1,000; second, 0.812; third, 0.523; fourth, 0.419; fifth, 0.410; sixth, 0.219; seventh, 0.124; eighth, 0.093; ninth, 0.069; tenth, 0.037. All the above data are obviously inexact. Toldt's are evidently cooked up, and not derived from observation; nor do the lengths mean the same thing, for of the early stages the head and trunk only were measured; of the later stages the head, trunk, and legs. A falser and more misleading device for studying growth has never been put in practice. The fœtus, too, being spirally coiled in early stages, cannot have its length determined accurately. Far better would it be always to determine the weight. The growth of the fœtus in weight has been most inadequately studied, although the weight is the *only* available measure of the growth of the fœtus as a whole. Hecker's data are perhaps the best. The weights are in grams:

Month.	Maximum.	Minimum.	Average.
Third	20	5	11
Fourth	120	10	57
Fifth	500	75	284
Sixth	1,280	375	634
Seventh	2,250	780	1,218
Eighth	2,438	1,093	1,569
Ninth	2,906	1,500	1,971
Tenth	....	1,562	....

The range of the maxima and the minima suggests that errors in the determination of the ages may have occurred—such errors of a month are not rare with obstetricians. These figures may be compared with Fehling's, given in the preceding section.

Appended here are Hecker's data as to the weight of the placenta in grams, and the length of the umbilical cord in centimetres:

Month.	No. of obs.	Placenta.	Cord.
Third	3	36	7
Fourth	17	80	19
Fifth	24	178	31
Sixth	14	273	37
Seventh	19	374	42
Eighth	32	451	46
Ninth	45	461	47
Tenth	62	481	51

2. *Weight of the New-born Child.*—It is subject to very considerable variations. For middle Europe the average may be held to be about 3,340 gm. for boys, 3,190 gm. for girls, the latter being somewhat lighter. The variations are very great, ranging from 1,000 to 5,000 gm. For instance, the following table is given by Pfannkuch, who unfortunately jumbles the two sexes together:

Kilograms.	Obs.	Kilograms.	Obs.
1.50 to 2.0	23	3.00 to 3.25	150
2.00 to 2.25	36	3.25 to 3.50	115
2.25 to 2.50	52	3.50 to 3.75	79
2.50 to 2.75	90	3.75 to 4.00	46
2.75 to 3.00	110	4.00 to 4.50	13

It will be noticed that the maximum number of cases (150) falls between 3.00 and 3.25 kgm., and that the further the weight is removed on either side, above or below, from this mean, the fewer are the cases. The tables by other authors show the same general results, with usually slight differences in the quantitative values. For the most part these tables cannot be combined with one another, for they nearly all fail to fulfil some obvious requirement of good statistics; indeed, amateur statistics are generally provoking to the expert. It is, therefore, not desirable to attempt an analysis of the recorded data. As an example of statistics at once valuable and grossly defective, the following table is given after Siebold. The author gives the weights in pounds, but has neglected to say, as is necessary in Germany, what kind of pounds; hence the metric equivalents cannot be calculated. Moreover, the number of cases weighing even pounds and half-pounds is far in excess of those weighing pounds, and one-fourth or three-fourths, which shows inaccurate weighing, of course. To correct this the quarter-pound groups of the original table are condensed into half-pound groups:

Weight in lbs.	Boys.	Girls.	Weight in lbs.	Boys.	Girls.
4.0 to 4.5	4	10	7.5 to 8.0	286	200
4.5 to 5.0	19	24	8.0 to 8.5	101	44
5.0 to 5.5	44	53	8.5 to 9.0	79	42
5.5 to 6.0	172	195	9.0 to 9.5	15	14
6.0 to 6.5	220	235	9.5 to 10.0	7	2
6.5 to 7	353	353	10.0 to 10.5	..	1
7.0 to 7.5	286	240	10.5 to 11.0	..	1

The extremes recorded in medical literature are very far apart, and statements of excessively large size are by no means rare, but can be received with incredulity only, as, for instance, the case reported of a still-born child weighing 8,250 gm.! (*Berliner klin. Wochenschr.*, 1878, No. 14.) Vierordt gives as the accredited extremes 717 gm. (Ritter), and 6,123 gm. (Wright).

The factors which determine the weight at birth are very obscure. It is, of course, safe to say, vaguely, that it depends on the nutrition of the fœtus; it is probable that individual differences in the rate of growth exist before as well as after birth, and it is probable that the length of gestation is the most influential single factor, to judge from my own experiments on the growth of mammals.

It has been demonstrated that the variations in the weight of the child depend upon various maternal circumstances.

First. It is correlated with the age of the mother, as is shown in the following table, giving the weight of the children in grams according to three observers:

Age of the mother.	Ingerslev.	Fassbender.	Petersson.
15 to 19 years	3,241	3,271	3,451
20 to 24 years	3,299	3,240	3,485
25 to 29 years	3,342	3,333	3,591
30 to 34 years	3,375	3,367	4,062
35 to 39 years	3,428	3,292	3,591
40 to 44 years	3,326		3,676

From such tables we learn that very young mothers have the smallest children, and those of about thirty-five years the heaviest. It is much to be regretted that the tables do not show the correlation by single years, and also the number of observations.

Second. The weight of the child increases with the weight (Gassner) and length (Frankenhäuser) of the mother. Gassner states that the weight of the child is to that of the mother as 1 to 19.13, or 5.23 per cent. of the maternal weight. Frankenhäuser states that if the height of the mother is less than 4 feet 6 inches, the child weighs 6 lbs. 15 oz.; if it is 4 feet 6 inches to 4 feet 11 inches, the child weighs 6 lbs. 25 oz.; if it is more than 4 feet 11 inches, the child weighs 7 lbs. 3 oz.

Third. The weight of the child increases according to the number of previous pregnancies, as indicated by the following table:

Number of pregnancies.	(Hecker.) Gm.	(Ingerslev.) Gm.
One	3,201	3,254
Two	3,330	3,391
Three	3,353	3,400
Four	3,360	3,424
Five	3,412	3,500
Six	3,353	

Here again we encounter faulty statistics, for it is not shown that we have any other effect than that of age, for the conclusion claimed cannot be established until it is proved that primiparæ have smaller children than multiparæ *of the same age.*

Fourth. Negri has maintained (*Annali di obstetricia*, 1885) that the compilation of three hundred and thirty-three observations shows that the children of women whose menstruation is early are larger than the children of those whose first menstruation is late.

Fifth and sixth, the influence of race and climate, which have not yet been subjected to any proper exact study.

In conclusion, I may add that it seems to me probable that all these influences produce their effect principally by prolonging or abbreviating the period of gestation. In other words, the variations in the weight of children at birth are to be referred immediately to two principal causes: (1) Differences in the age at birth; (2) individual differences of the rate of growth in utero.

3. *Growth of Infants.*—(*a*) *Alteration in weight during the first week.* There is an interruption of the normal rate of growth during a few days after birth, both in man and other mammals (Section IV.). It lasts for a variable period, and is variable in degree. In most cases, with the human species, it is so great as to cause an actual loss of weight, but frequently it shows itself only as retarded growth. A great many authors have written upon this subject, but there is not a single one who appears to have correctly understood the statistical relations. In fact, the discussion thus far has turned upon the question whether a loss or a gain of weight is normal and physiological. That question is of little importance, since it is now settled that the retardation of growth is constant. It depends on the degree of retardation whether there is merely a small gain or an actual loss. During the first month the average daily increase is about 35 gm. (Fleischmann), but during the first two or three days, or sometimes more, the rate of increase is very much less, often even negative. Gregory, for instance, gives the following data:

Day	1	2	3	4	5	6
Number observed	33	33	33	33	33	33
Weight change, grams	−139	−64	+33	+50	+50	+36

The retardation of the growth is prolonged by defective nutrition, of which the cause may lie in either the mother or the child, and by illness of the child. A healthy baby ought to get back to its initial weight by the sixth or seventh day, and failure to reach the initial weight by the ninth day may be taken as an indication of illness.

The cause of the post-natal retardation is not fully elucidated. That it is not due to the mother's condition is

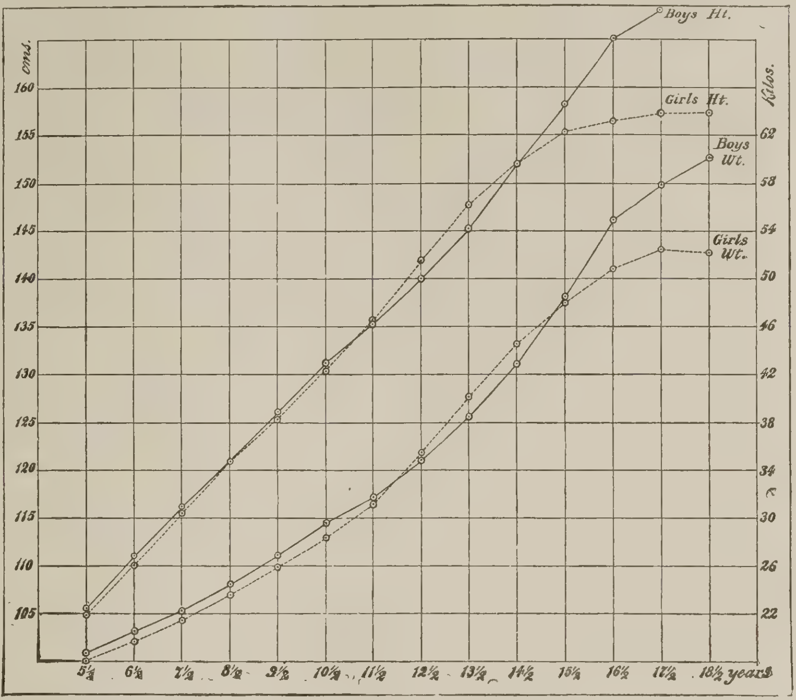

FIG. 2350.—Graphic Representation of the Growth of Boston School Children, based on the whole number of Bowditch's observations, irrespective of nationality of parents.

shown by two considerations: (1) The retardation occurs also in chicks at hatching, although they are not dependent on the parent for nutrition; (2) Ingerslev put sixteen children, just born, to wet-nurses, who had borne four to five days previously and gave abundant milk, nevertheless the children all lost weight. It seems probable that the loss is due to the establishment of respiration, and to the increased expenditure (metabolism) of the body to maintain the normal temperature. During gestation and incubation the parent supplies caloric to its young, but after birth (or hatching) the young is self-dependent, and rapidly wastes its tissues to keep up its body warmth.

(*b*) *For the growth from the first to the fifty-second week* we must depend chiefly on—(1) the careful compilation given by Meek and quoted by Vierordt, in which, however, the sex, nutrition, race, and social condition of the children are not considered, all factors which have a very great influence on the weight; (2) the observations of Albrecht (*Central-Zeitung f. Kinderheilkunde*, 1879, No. 7), who followed the growth of eighty children at Berne. From Meek the following data are excerpted:

Week.	No. of observations.	Weight, gm.	Week.	No. of observations.	Weight, gm.
First	22	3,228	Twenty-eighth	21	7,187
Second	25	3,367	Thirty-first	19	7,524
Third	31	3,412	Thirty-fourth	19	7,842
Fourth	31	3,532	Thirty-seventh	18	8,126
Seventh	33	4,103	Fortieth	17	8,344
Tenth	34	4,600	Forty-third	17	8,533
Thirteenth	36	5,022	Forty-sixth	17	8,760
Sixteenth	34	5,529	Forty-ninth	15	8,995
Nineteenth	32	5,864	Fiftieth	15	9,102
Twenty-second	26	6,497	Fifty-first	14	9,198
Twenty-fifth	23	6,925	Fifty-second	8	(10,172)?

Albrecht states that in his experiments, taking the weight of the child at 3,300 gm. at birth, the following is the average daily increase for each month in grams:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Grams	30	29	29	24	20	18	14	11	11	9	8	7

The corresponding figures by Bouchaud are:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Grams	25	23	22	20	18	17	15	13	12	10	8	8

By Fleischmann:

Month	1	2	3	4	5	6	7	8	9	10	11	12
Grams	35	32	28	22	18	14	12	10	10	9	8	6

The individual variations are very great, and the growth of any individual goes by fits and starts. A considerable delay in growth is not important, even if lasting for several, say three or four, weeks, as it is counterbalanced by a subsequent excessively rapid growth.

(*c*) *Concerning the Growth from the End of the First to the End of the Fifth Year.*—No statistics sufficiently extensive and accurate to be worth quoting are known to me. Quetelet's, which are often repeated; are misleading, because he weighed only children which in his judgment were well developed; hence, his figures do not give an average of anything except Quetelet's notion of what a child ought to be, which is now definitely known to be essentially different from what children are.

5. *Growth of Children.*—Concerning school children we possess a good many valuable data. The best statistics by far are those of Bowditch. The average weights obtained by him are given in the accompanying table in kilograms; the clothes make up about eight per cent. of the weights given. The average standing heights, without shoes, is given for both sexes in the same table. These data refer to nearly twenty-five thousand measurements on the school children of Boston, Mass.

GROWTH OF BOSTON SCHOOL CHILDREN.

Age.	Boys.			Girls.		
	Height in cm.	No. of observations.	Weight, kgm.	Height in cm.	No. of observations.	Weight, kgm.
5 to 6 years	105.6	848	18.64	104.9	605	17.99
6 to 7 years	111.1	1,258	20.49	110.1	987	19.63
7 to 8 years	116.2	1,419	22.26	115.6	1,199	21.53*
8 to 9 years	121.3	1,481	24.46	120.9	1,299	23.61*
9 to 10 years	126.2	1,437	26.87	125.4	1,149	25.91
10 to 11 years	131.3	1,363	29.62	130.4	1,089	28.29
11 to 12 years	135.4	1,293	31.84	135.7	936	31.23
12 to 13 years	140.0	1,253	34.89	141.9	935	35.53
13 to 14 years	145.3	1,160	38.49	147.7	830	40.21
14 to 15 years	152.1	908	42.95	152.3	675	44.65
15 to 16 years	158.2	636	48.56	155.2	459	48.12
16 to 17 years	165.1	359	54.90	156.4	353	50.81
17 to 18 years	168.0	192	57.84	157.2	233	52.41
18 to 19 years	169.3	84	60.13	157.3	155	52.24

* In Bowditch's tables, as printed, incorrect numbers are given.

The results are more easily followed in the graphic representation, Fig. 2350; the ordinates represent the heights or weights, the abscissæ, the ages. We can distinguish three periods: (1) The steady growth of childhood, up to ten and one-half or eleven years in girls, to twelve or twelve and one-half in boys; (2) the period of præpubertal acceleration, when the growth is much more rapid, lasting in girls from eleven to fourteen or fifteen, in boys from twelve and one-half to sixteen and one-half; (3) the postpubertal decline. In girls the præpubertal acceleration begins earlier and is more marked than in boys; hence, though during childhood girls are smaller than boys, yet from twelve to fifteen they outstrip them, and are both taller and heavier than boys of the same age. Puberty ensues later in boys than in girls. The postpubertal falling off in growth is more rapid in girls than in boys; accordingly, after the fifteenth year boys gain fast over the girls. That the acceleration is really præpubertal is shown by the fact that the age of the first catamenia averages in Boston about fourteen and one-half years, so far as determined by the present imperfect statistics. Pagliani has proved the same relation in Italy. Most conclusive is the record of the growth of individuals, which demonstrates that the first menstruation is preceded by rapid, and followed by slower, growth.

Dr. Bowditch has shown, also, by his statistics that the children of American-born parents are, in the community of Boston, taller and heavier than children of foreign-born parents, a superiority which depends probably chiefly on the greater average comfort in which such children live and grow up, and partly upon differences of race and stock. The children of the well-to-do classes are taller and heavier than those of poorer classes. American (Boston) boys are taller for their age than English boys, concerning whom we have statistics, and are also heavier in proportion to their height; the comparison holds between the laboring classes and the upper classes both, as well as between boys taken without distinction. Incidentally it may be said that the popular conception of a "Yankee," as tall and slim, has no foundation in life, the Yankee, on the contrary, being stouter than the Englishman.

In general it may be said that growth is favored by healthful conditions; it is impaired by illness, probably, of any kind, but, of course, by some diseases much more than by others. It is favored by country more than by city life; by outdoor more than by sedentary occupations; by summer more than by winter; by vacation more than by attendance on school. A considerable body of statistical material on these and similar points is available, but unfortunately it is much scattered and has never been collated.

The growth of the organs calls for much further investigation. At present we can compare only the adult with the new-born child, but even of these the data are few. From Vierordt's compilation the following table is taken:

	NEW-BORN CHILD.		ADULT.	
	Weight in grams.	In per cent. of the body weight.	Weight in grams.	In per cent. of the body weight.
Skeleton	445	16.7	11,560	15.35
Muscle	625	23.4	29,880	43.09
Tendon		....		
Skin	337	....	4,011	
Brain	....	14.34	......	2.37
Suprarenals	8.5	.31	8.0	.014
Thymus	9.4	.54	5.0	.0086
Thyroid	6.5	.24	29.1	.05
Lungs	....	2.16	......	2.01
Heart	....	.89	......	.52
Liver	....	4.39	......	2.77
Kidney	....	.88	......	.48
Alimentary canal	....	2.53	......	2.34

The weights in grams and the percentages are from different authors. There are certain observations on the growth of organs, notably by Lorey, Frerichs, Bischoff, Bambeke, and Thoma, but the number of cases heretofore recorded is so small that no satisfactory statistics are possible.

It would be very interesting to know how the chemical composition of the body changes with age, and it is to be hoped that we shall soon have complete analyses of bodies at various ages.

6. *Size of Adults.*—No available statistics in regard to women are known to me, those referring to men, and taken from armies, are very extensive; the best worked out are the data in regard to the American army, as discussed by Gould and Baxter. The former had the material collected by the Sanitary Commission during the Rebellion; the records were hastily and inaccurately made by the single States, but the number of observations was so large that the errors may have corrected themselves to a considerable extent. Baxter, whose material was much more extensive and reliable, has not thought it worth while to tabulate the weights in proportion to age, but gives good tables of the stature.

GOULD'S TABLE OF THE MEAN WEIGHTS OF WHITE SOLDIERS.

Age.	No. of observations.	Weight, lbs.	Age.	No. of observations.	Weight, lbs.
16	216	121.03	36	184	149.29
17	456	128.02	37	167	148.81
18	1,100	133.93	38	153	147.22
19	1,150	137.05	39	123	146.38
20	1,357	141.38	40	98	150.01
21	1,446	143.06	41	61	146.30
22	1,351	143.60	42	102	146.97
23	1,108	144.31	43	73	145.62
24	1,059	146.31	44	83	152.79
25	745	146.84	45	67	147.06
26	599	147.05	46	37	146.97
27	551	146.93	47	19	145.05
28	512	147.21	48	35	146.82
29	386	145.51	49	10	145.19
30	395	147.62	50	21	138.06
31	242	147.65	51	12	144.25
32	298	146.00	52	10	139.49
33	225	148.53	53	11	151.15
34	225	148.29	54	8	159.60
35	339	145.57	Over 54	20	143.49

From this table the increase in weight is seen to continue up to about the thirty-fifth year, but the figures of the weights are irregular after the number of observations falls below 600. That the period of growth reaches to this age is more clearly shown by Baxter's table of the height at different ages.

TABLE OF AGES AND CORRESPONDING HEIGHTS (WITHOUT SHOES) OF 190,621 AMERICAN-BORN WHITE MEN FOUND FIT FOR MILITARY SERVICE.

Age.	Number of observations.	HEIGHT.	
		Inches.	Metre.
Under 17 years	468	64.11	1.6284
17 years	937	65.67	1.6675
18 years	30,456	66.39	1.6863
19 years	14,994	67.07	1.7036
20 years	11,526	67.51	1.7148
21 years	14,146	67.78	1.7216
22 years	10,479	67.92	1.7252
23 years	8,907	68.01	1.7275
24 years	7,335	68.02	1.7277
25 years	7,940	68.05	1.7285
26 years	6,986	68.09	1.7295
27 years	6,351	68.11	1.7300
28 years	6,033	68.13	1.7305
29 years	4,447	68.17	1.7315
30 years	6,256	68.18	1.7318
31 years	5,562	68.20	1.7323
32 years	4,635	68.20	1.7323
33 years	3,939	68.29	1.7346
34 years	2,782	68.35	1.7361
35 years	4,966	68.47	1.7391
36 years	4,138	68.28	1.7343
37 years	4,172	68.26	1.7338
38 years	4,014	68.24	1.7333
39 years	3,402	68.23	1.7330
40 to 45 years	15,750	68.23	1.7330

These tables show that it is necessary to be extremely cautious in fixing upon any year to mark the adult age, for the cessation of growth is so gradual that its ending cannot be determined. In practice, it is convenient and sufficiently accurate to call twenty-five the adult year; for women it ought probably to be somewhat less. That the tables are far from what we could wish is true, chiefly owing to the inherent defects of the original observations; we must also regret that Baxter did so much less than his material would have permitted. But, on the other hand, both Baxter and Gould are far in advance of their predecessors. Anthropometry has been much written upon. Baxter gives an excellent review of the subject, with sketches of the many mystical laws announced by older authors upon human proportions, but we still lack a good general treatise upon vital statistics.

IV. The Laws of Mammalian Growth.—Growth is a subject as yet but little investigated, and this section is based on Minot's experiments, made chiefly on guinea-pigs, but including also rabbits and chickens. The preceding table summarizes the most important general results of these experiments; the table refers only to male guinea-pigs, it not being necessary to include the females or other animals.

Growth of Male Guinea-Pigs.

Age.	Number of observations. Grams.	Average weight. Grams.	Increase over last measurement. Grams.	Average daily increase. Grams.	Daily per cent. increase. Grams.
0 day...	200	70.8			
1 to 3 days..	138	70.8	1.0	0.0	0.0
4 to 6 days..	133	82.6	11.8	3.9	5.6
7 to 9 days..	142	96.2	13.6	4.5	5.5
10 to 12 days..	148	109.7	13.5	4.5	4.7
13 to 15 days..	150	126.2	16.5	5.5	5.0
16 to 18 days..	152	141.7	15.5	5.2	4.1
19 to 21 days..	151	158.4	16.7	5.6	3.9
22 to 24 days..	152	173.2	14.8	4.9	3.1
25 to 27 days..	145	187.8	14.6	4.9	2.8
28 to 30 days..	141	203.8	16.0	5.3	2.8
31 to 33 days..	140	215.6	11.8	3.9	1.9
34 to 36 days..	136	226.9	11.3	3.8	1.7
37 to 39 days..	129	240.2	13.3	4.4	1.9
40 to 50 days..	149	272.9	32.7	3.0	1.2
55 to 65 days..	155	327.1	54.2	3.6	1.3
70 to 80 days..	155	383.9	56.8	3.8	1.2
85 to 95 days..	152	434.4	50.5	3.4	.9
100 to 110 days..	102	481.6	47.2	3.1	.7
115 to 125 days..	75	522.8	41.2	2.7	.6
130 to 140 days..	67	529.8	7.0	.5	.1
145 to 155 days..	72	562.9	33.1	2.2	.4
160 to 170 days..	75	590.5	27.6	1.8	.3
175 to 185 days..	76	604.7	14.2	.9	.2
190 to 200 days..	70	627.0	22.3	1.5	.2
205 to 215 days..	61	663.3	36.3	2.4	.4
8 months.......	56	672.0	8.7	.3	.05
9 months.......	53	737.7	65.7	2.2	.3
10 months.......	56	761.6	23.9	.8	.1
11 months.......	68	770.3	8.7	.3	.04
12 months.......	68	793.9	23.6	.8	.1
13 months.......	66	754.9	− 39.0	− 1.3	− .2

The last column but one shows that the daily increase during the first three days is zero. This is due to the postnatal retardation, which is very marked in guinea-pigs, as it is also in man. The exact data are:

	Weight. Grams.	Increase.
At birth....................................	70.8	....
One day....................................	68.9	−1.9
Two days....................................	70.0	1.1
Three days....................................	73.4	3.4
Four days....................................	77.3	3.9

The daily gain slowly increases till about the fourteenth day, and then slowly but steadily falls off. The observations are so few in number that there are many irregularities, which need not be heeded in this article. Usually the absolute increment is taken as the measure of the *rate* of growth, which is not justifiable. To show the rate of growth—as well as the observations permit—is intended by the last column, which gives the daily increase for each period, calculated at a *percentage of the weight at the beginning of that period.* We thus secure values for legitimate comparisons, because the absolute increment during any period is the product of the amount of growing material multiplied by the rate of growth; hence, if the rate is to be found, the growing amount and the absolute increment being known, the amount must be divided by the increment; this was done, and the fractions so obtained converted, for readier comparison, into percentages. As regards the guinea-pig, it shows at once that as soon as the animal has recovered from the postnatal retardation its rate of power of growth declines steadily. The observations of Fehling upon the embryos of man and rabbits show that this retardation in the relative rate of growth begins long before birth, and observations on plants make it probable that it has its beginning with the commencement of histological differentiation. This fact leads, of course, to the assumption that the vital powers undergo a steady decline, and that instead of there being a period of development, followed at maturity by a period of decline, there is a continuous decline, of which the final term is the natural death of the organism. We must, in fact, fundamentally change our conceptions of the phases of life. A man builds a wall, which keeps growing, but as the man becomes tired it increases more slowly, and stops when he is worn out. So the vital forces build the body, which develops, but all the while the forces are losing their power. The comparison is somewhat faulty, but may help to a clearer conception of decline during development.

The constant loss in the rate, which appears to be the fundamental law of growth, at least in mammals and probably in all metazoa, may be shown in another manner very strikingly. If we calculate at what age after birth the animal will have added ten per cent. to its original weight, and then the age at which it will have again added ten per cent. to its weight at the end of the first period, and so on, we obtain the following table:

Growth of Male Guinea-Pigs.

Weights increasing at the rate of ten per cent. Grams.	Age at which they fall. Days.	Differences. Days.	Weights increasing at the rate of ten per cent. Grams.	Age at which they fall. Days.	Differences. Days.
70.80	0.0	....	244.34	38.8	5.2
77.88	4.1	4.1	268.77	43.7	4.9
85.66	5.6	1.5	295.64	50.2	6.5
94.22	7.7	2.1	325.20	59.2	9.0
103.64	9.6	1.9	357.72	68.6	9.4
114.00	11.8	2.2	393.49	77.3	8.7
125.40	14.0	2.2	432.83	88.6	11.3
137.94	16.2	2.2	476.11	100.7	12.1
151.73	18.7	2.5	523.72	120.0	19.3
166.90	21.7	3.0	576.09	160.6	40.6
183.59	25.3	3.6	633.69	201.3	40.7
201.94	28.7	3.4	647.05	258.2	56.9
222.13	33.6	4.9	766.75	298.3	40.1

To make the first addition of ten per cent. requires long, 4.1 days, owing to the postnatal retardation; the second addition takes only 1.5 days; the succeeding additions occupy increasing periods, overlooking slight irregularities. In other words, the older the animal the longer it requires to add ten per cent. to its weight. In this table, also, we see the decline progressing during the so-called period of development.

The same law of decline holds true for rabbits and chickens, and also for man. In man there is a very noteworthy modification, produced by the very marked præpubertal acceleration of growth, during which the decline is interrupted, as shown by my calculations from Bowditch's tables; but compared with the whole course of decline the interruption is but slight, and is counterbalanced by an over-rapid postpubertal decline. No essential importance is to be assigned to this phenomenon, since it is well known to embryologists that during development there are often displacements in time and in the growth of individuals. Minot observes that an accidental quickening or slowing of growth is followed by a reverse period, in the first case of slowing, in the second of quickening. There appears, therefore, no objection to the conclusion that in man also the period of apparent development is a period of real decline.

This leads us to the corollary that the stoppage of growth is not due to the reaching of maturity, but is merely the final term of a series of losses. It has been asserted by Herbert Spencer, Carpenter, and others, that there is an inherent opposition between growth and reproduction, because the assimilative processes cannot perform enough to supply material for the growth of mother and offspring both. These authors and their followers see in the commencement of reproduction the beginning of a tax upon the organism which stops its growth; but as Minot has pointed out, the cause is mistaken for the effect, and probably the loss of vital force is the stimulus causing reproduction. Certainly the decline, which goes on from birth, cannot be caused by a phenomenon which begins only when the decline is nearly completed. Direct observations show that Spencer's view is erroneous, for growing guinea-pigs will bear one-third of their own weight of young while growing, and still reach as full an adult size as those producing no young (Hensen). My own experiments suggest that they become even larger. We thus learn that the fundamental conception on which Spencer's theory rests is imaginary—that conception being, that the assimilative power is approximately equal only to the needs of the growing animal. In reality there is a large excess of assimilation possible within normal limits.

The next point to be noticed is that animals tend, as they grow, to approximate to the special size of the species. This shows itself by the fact that the range of variation is less for adults than for the young. The following table shows this: The first column gives the age; the second column gives the average variation above the mean weight for that age, the variation being expressed as a percentage; the third column gives the variation below the mean—averages being based on 4,200 observations in all

Male Guinea-Pigs.

Age.	Variation above. Per cent.	Variation below. Per cent.
0 to 0 day	19.51	19.49
1 to 15 days	18.95	18.99
16 to 30 days	17.13	16.87
31 to 65 days	15.68	16.31
70 to 140 days	12.12	13.31
145 to 215 days	7.52	7.48
8 to 12 months	10.66	9.72
13 to 17 months	10.38	11.41
18 to 24 months	12.10	10.82

The variation of adults is barely over half that at birth in range. Remarkable is the low variation from 145 to 215 days, and from 8 to 12 months. The higher values for older periods is perhaps due to variations in obesity, which we know from common observation increases in the human species with age. The growth of an individual also indicates the existence of this tendency to attain the typical adult size; if the growth of the animal is retarded by illness, after recovery the growth is accelerated to make up. This has practical importance, for, unless the illness of a child is very prolonged, no permanent effect upon its size is to be anticipated.

The size of an animal or the limit of its growth depends upon, first, the rate, and second, the duration of its growth. This is well shown by comparing man with the rabbit and the guinea-pig, as to the average daily growth. A man acquires a weight of about 63,000 gm. in twenty-five years; a rabbit, of the larger breeds, about 2,500 gm. in one year, and a guinea-pig about 750 in the same period. For man add 280 days, for rabbits 30 days, for guinea-pigs 68 days, on account of the period of gestation.

Man.................. 63,000 gm. ÷ 9,139 + 280 = 6.69 gm. per diem.
Rabbit................. 2,500 gm. ÷ 365 + 30 = 6.30 " " "
Guinea-pig........... 750 gm. ÷ 365 + 68 = 1.73 " " "

Man grows about as fast as a rabbit, but becomes much bigger, because he grows longer; but the rabbit is bigger than the guinea-pig, because he grows much faster. This is matter of common observation; all that we gain from our calculation is a quantitative expression more suited for ready comparison.

Of course, the whole shaping of the organism depends upon variations in the growth rates of the single parts, but what causes such variations is unknown. Many writers have sought to account for the variations by purely mechanical factors, principally strain and pressure; but although such assumptions have been very frequently put forward by His, van Beneden, Kölliker, and a host more, they must all be condemned as more or less ill-considered speculations. A growing trout assumes a certain form; why? because it is its inherited tendency; of the physiological nature of that tendency we know hardly anything, except that it is *not* mechanical, but only an unexplained growth force.

Literature.—The only general works are the very important treatise of Vierordt in Gerhardt's "Handbuch der Kinderkrankheiten," Bd. 1, Abth. 1, pp, 219–290; Davenport's treatise in the second volume of his "Experimental Morphology" (1899); and the useful summaries given by Preyer in his "Physiologie des Embryos," by Hensen in the sixth volume of Hermann's "Physiology," and Daffner, in "Das Wachstum des Menschen" (1897). The number of special papers is very large; a few references are given below; for additional ones consult Vierordt. *Charles Sedgwick Minot.*
Revised by *R. P. Bigelow.*

I. Growth of Fœtus.—See Preyer's Specielle Physiologie des Embryo for a synopsis of the observations and references to the literature.—Pagliani: Lo Sviluppo umano, per età, sesso, etc., 8vo, Milano, 1879.—Fehling: Beiträge zur Physiologie des Placentenstoffverkehrs. Arch. f. Gynäk., xi., 1877, pp. 523–527.
II. Weight at Birth.—Rumpe: Arch. f. Gyn., xx., 117.—Ahlfeld: *ibid.*, xii., 489.—Lorey: Jahrb. Kinderheilk., N. F., xii., 260.—Ingerslev: Nord. Med. Ark., vii., 1875—Frankenhäuser: Monatschr. Geburtsk., xiii., 170.—Elsässer: Henke's Zeitsch., xxxvii., 2.—Wagner: Centralbl. f. Gynäk., 1885, 359.—Negri: *ibid.*, 1886, p. 58.
III. Growth of Infants.—Hesse: Arch. f. Gynäk., xiv., 491, and xvii., 150.—Petersen: Schmidt's Jahrb., Bd. 196, p. 31.—Hofmann: Neue Zeitschr. Geburtsk., xxvi., 145.—Siebold: Monatschr. Geburtsk., xv., 337.—Pfeiffer: Jahrbücher f. Kinderheilk., xix., 142.—Biedert: *ibid.*, xix., 275.—Woronoff: *ibid.*, xxii., 254; abstract in Schmidt's Jahrb., Bd. 205, p. 47.—Wolff: Centralbl. f. Gynäk., 1885, p. 16.—Rezmarozky: Arch. f. Gyn., v. For further literature see Vierordt, *loc. cit.*
IV. Growth of Children.—Bowditch: The Growth of Children, Boston, 1877; also, The Growth of Children (a supplementary investigation), Boston, 1879; both republished from Reports of the Massachusetts State Board of Health.—Peckham: The Growth of Children, from Sixth Annual Report State Board of Health of Wisconsin.—Pagliani: Lo Sviluppo umano per età, sesso, etc., Milano, 1879; and Sopra alcuni fattori dello Sviluppo umano, Torino, 1876.—Malling Hansen: Gewicht der Kinder, Copenhagen, 1883; and Tägliche Wagungen, etc., Copenhagen, 1884.—Theile: Nova acta, xlvi., 3, 1884.—Ménard: Gazette Méd., Paris, January 9th, 1886.—Roberts, C.: Relative Increase in Size of the Body. Report of Brit. Assn. Adv. Sci., 1881.—Porter, W. T.: Growth of St. Louis School Children. Trans. Acad. Sci. St. Louis, 1893–94; and Pub. Amer. Statis. Assn., 1894-95.—Daffner, F.: Das Wachstum des Menschen, Leipzig, 1897.
V. Anthropometry.—See the General Treatise of Roberts; Gould's Statistics, published by the U. S. Sanitary Commission; and Baxter: Statistics of the Provost-General's Office, 2 vols., 4to, Washington, 1876. Baxter gives an extensive bibliography.—Davenport, C. B.: Statistical Methods, New York, 1899.
VI. Growth of Animals.—Minot: Proc. Society of Arts, Boston, p. 50, 1884.—Hensen und Edelfsen: Arbeiten Physiol. Inst. Kiel, pl. i. Kehren: Arch. f. Gyn., i., 224.

GUACAMPHOL, the camphoric acid ester of guaiacol, occurs in white, needle-like crystals or powder, and is tasteless and odorless, and insoluble in the ordinary solvents. It is said to pass unchanged through the stomach, and to split up in the intestines into guaiacol and camphoric acid; so it has been employed as an intestinal antiseptic, particularly in tuberculous diarrhœas. It is especially recommended, however, by Kaminer and Lasker, for combating the night sweats of pulmonary tuberculosis. The dose is 0.5–1 gm. (gr. viij.–xv.) in capsule at bedtime. *W. A. Bastedo.*

GUACO.—The drug at present known by this name is only one of a number of products known by it in tropical America. It is the leaves of *Willoughbœa* Neck, or *Mikania* Willd., probably of more than one species (fam. *Compositæ*). It is a native of South America, and grows also, either wild or introduced, in the West Indies. Guaco has a great reputation among the inhabitants of many South and Central American countries as an antidote to snake bites, and as a sort of corollary it has been supposed to be useful in hydrophobia, cancer, cholera, epilepsy, syphilis, etc. Fauré separated an amorphous bitter principle (which is probably not chemically pure) which he has called *guacin.* An odorous principle that appears to be present in the fresh, must be mostly dissipated in the dried, leaves. There is nothing in its chemical or evident physical properties that should lead one to regard guaco as other than a mild aromatic bitter, of the Eupatorium order.

In its native regions it is preferably given in the fresh state. Here the dried leaves may be prepared in any of the usual ways, and rather freely administered.

W. P. Bolles.

GUAIAC, including Guaiac Wood, Guaiaci Lignum, or *Lignum Vitæ.* "The heart-wood of *Guaiacum officinale* L. and of *G. sanctum* L. (fam. *Zygophyllaceæ*)" (U. S. P.), and Guaiac, Guaiac Resin, Guaiaci Resina, or "*Gum Guaiac.*" "The resin of the wood of *Guaiacum officinale* L." (U. S. P.). These are small evergreen trees of northern South America and the West Indies, having the habit of a small apple-tree, and forming a brilliant mass of bright blue, when in full bloom.

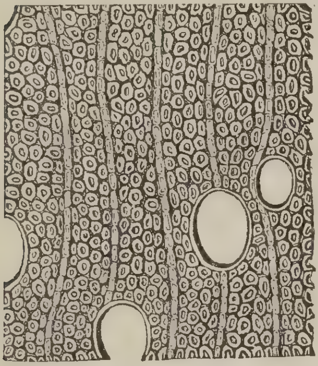

FIG. 2351.—Section of Guaiacum Wood. (Baillon.)

Guaiacum wood was carried to Europe soon after the discovery of the West Indies (early in the sixteenth century), and made a rapid reputation for itself as a remedy for syphilis and gout, a reputation that it unfortunately very soon lost again in great measure. Two products of the tree are imported—the wood, which if of fair size and soundness, goes to the turners to be made into pulley-sheaves, mallets, mortars, tool handles, etc., and the crude resin, rudely obtained from the living tree or fresh wood.

The wood comes in logs several feet in length, and from two to six or eight or more inches in diameter, often irregularly crooked and branching; they consist, excepting the smallest, of a bright yellow, hard *alburnum,* and a very dark greenish-brown, exceedingly hard and heavy heart, consisting of very much thickened wood cells, and an abundance of a peculiar composite resin. This wood is almost as hard and heavy as ivory, and turns the edges of tools not especially sharpened for it. That which reaches the drug market consists principally of the turnings and refuse of what is manufactured for the purposes above named. It should consist only of the brown or green heart-wood, which is heavier than water, to which it does not impart its color. Upon the addition of nitric acid, if it has not been deprived of its resin, it should give a dark, bottle-green color. The resin, of which there should be about 25 per cent., is the only active constituent, so that its properties are also those of the wood.

The resin, which is obtained partly by incising the trees, and partly as a spontaneous exudation, also sometimes forced out from the wood by heat, is a crude and impure substance. The officinal description is as follows: In irregular masses, or subglobular pieces, externally greenish-brown, internally of a glassy lustre, and, in recent guaiac, usually reddish-brown, transparent in thin splinters, fusible, feebly aromatic, the odor becoming stronger on heating; taste somewhat acrid; powder grayish, turning green on exposure to air.

Soluble in potassium or sodium hydrate T. S. and in alcohol; the alcoholic solution is colored blue on the addition of tincture of ferric chloride.

It is very brittle when cold, plastic with slight heat.

Composition.—It contains about seventy per cent. of *guaiaconic acid,* a yellow or brown, brittle, amorphous resin; ten of *guaiaretic acid,* which is crystalline; nine or ten of *guaiacic acid,* something like guaiaconic acid, and three or four of gum, besides a little volatile oil, ash, coloring matter, and various impurities.

Action and Use.—The reputation of guaiac depends upon clinical evidence entirely, and has had spells of waxing and waning. It is stimulating, or in large doses irritating to mucous membranes and markedly increases their secretions, thus acting as a laxative. The high estimate early placed upon it in syphilis has disappeared since the real efficiency of mercury and iodine has been established. In gout, although perhaps useful, it is certainly no specific; as an emmenagogue it is no better nor worse than many others. In chronic and mild subacute rheumatism, and in rheumatic arthritis, the evidence in its favor is strong. It is perhaps one of the best remedies for these intractable maladies. It is considerably used in inflammatory conditions of the throat and fauces, especially when there is deficient secretion.

Administration.—The dose of guaiac (resin) is from 0.5 to 2 gm. (gr. viij.–xxx.). It may be given in pill or powder, but the tinctures, of which there are two,—one simple (*Tinctura Guaiaci,* U. S. P., strength 20 per cent.), made with alcohol, and one associated with ammonia (*Tinctura Guaiaci Ammoniata,* U. S. P., strength 20 per cent.), made with aromatic spirit of ammonia,—are more generally used in doses of 2 to 4 c.c. (fl ʒ ss.–i.). Both become turbid upon mixing with water, and are oftenest given in milk. Guaiac wood is used as an adjuvant in the Compound Syrup of Sarsaparilla.

W. P. Bolles.

GUAIACETIN, pyrocatechin-mono-acetic acid ($C_6H_4.OCH_2.COOH.OH$), is a white, odorless, crystalline powder, readily soluble in water. Nièd and Meitner have used it with benefit in tuberculosis, claiming for it the special advantages that it promptly lowers temperature, lessens the mucous secretion, and diminishes the night sweats. It is an admirable stomachic (Meitner), and so may be continued even when chronic gastritis exists. The dose is 0.5 gm. (gr. viij.) three times a day in solution or capsule.

W. A. Bastedo.

GUAIACOL.—*Methyl-pyrocatechin.* $C_6H_4.OCH_3.OH$. Guaiacol constitutes from sixty to ninety per cent. of wood creosote, from which it is separated by fractional distillation, the boiling point of guaiacol being 206° to 207° C. Specific gravity, at 15° C., 1.33. It is a colorless liquid, with a strong aromatic odor, slightly soluble in water, 1 part to 85, readily soluble in alcohol, ether, glycerin, and oil. Guaiacol may also be prepared synthetically from catechin, and by the dry distillation of guaiacum resin. From these sources it is obtained in colorless, prismatic crystals. These are considered to be absolutely pure guaiacol, and are official in the Paris Codex. The guaiacol of commerce is very variable in strength and often very impure, the impurities being such as are common in creosote and are the result of careless distillation. The adulteration is evident by the lower specific gravity, the stronger odor, and by becoming darker upon exposure. The pure guaiacol, with concentrated sulphuric acid, gives a faint yellow coloration which is changed to a cherry-red by the addition of acetone; the impure article gives a more or less red color with the acid alone.

Guaiacol is absorbed from the stomach or intestines, from the unbroken skin, and by inhalation. It is rapidly excreted and may be detected in the urine, saliva, or perspiration within fifteen minutes. In twenty-four hours it is entirely excreted. Guaiacol may be detected by distilling the solution with dilute sulphuric acid, and adding to the distillate a small quantity of a dilute solution of liquor ferri sesquichlorati (two or three drops to a test tube of water). If guaiacol is present a reddish-brown color is developed, the intensity of which depends upon the amount of guaiacol.

The action of guaiacol is the same as that of creosote, the advantages claimed for it being its greater purity and more definite composition. Locally, it is antiseptic and analgesic, and when administered by the mouth it exercises the same effect upon the stomach and intestinal tract. Its action after absorption is as yet not well understood. Many consider that its beneficial effects are produced simply by its tonic and stomachic action; others, including Schueller who brought it to the notice of the profession, ascribe its virtues to a direct antiseptic action which destroys all bacterial growth that comes under its influence. Another and more recent view is that it combines with the toxins of the pathogenic bacilli, forming soluble compounds which are rapidly eliminated by the excretions.

The superiority of guaiacol over creosote, in the treatment of tuberculous conditions, was first advocated by Prof. Max Schueller, of Berlin, in 1880.[1] In his work, the author relates the experience which he derived from administering various drugs to animals affected with tuberculosis. Creosote, guaiacol, benzoate of soda, and many similar drugs had been experimented with and he had selected guaiacol as the most effective. In 1891[2] he published a second treatise in which he reviewed the work which he had carried on during the intervening years, and explained in detail his method of employing it. In all forms of tuberculosis he administers it continuously in small doses, as in his experience large doses were not of any special value. He particularly insists upon its continued use, which should be followed for some months after the bacilli have disappeared. He advocates, for children, a dose of two or three drops, and for adults one of from three to five drops, four times daily. He gives it in plain water, to which a little table salt has been added, and sometimes in milk, wine, or spirits. In surgical tuberculosis, in addition to its internal use, he also injects it directly into the diseased part, or, if the surface of the skin has already been destroyed, he curettes the tissues and applies the guaiacol directly to the denuded surface.

Although guaiacol has not replaced creosote in the treatment of tuberculosis, it is very extensively employed and is one of the drugs looked upon with favor in this disease. Experience has shown that it does not possess all the virtues which were originally attributed to it, but reports indicate that it is used with much success and by many it is thought to be of great value. Its use is not limited to tuberculous conditions. It has been employed with favorable results in all septic diseases, in puerperal and typhoid fevers, erysipelas, pleurisy, bronchial catarrh, whooping-cough, and many local inflammatory conditions.

The method of administering guaiacol varies. Many prefer to give it in continuous small doses, from three to five minims three times a day, as advised by Schueller, while others adopt the ideas of Sommerbrodt in the use of creosote, and give it in rapidly increasing doses for the purpose of saturating the system and acting directly upon the pathological processes. With this in view the quantity may be increased by one drop at each dose until fifteen drops, three times a day, are given, and this dose is to be maintained for an indefinite period. It has been demonstrated that as much as sixty minims three times a day may be given without ill effect.[3] When the remedy is given in large doses or when its use is continued for a prolonged period, the action of the kidneys should be watched, as any interference with this function would cause an unexpected retention of the drug in the system.

It should always be administered well diluted, in milk, wine, spirits, or water. The addition of a vegetable bitter, as tincture of orange, gentian, or cardamoms, serves to disguise its taste and to add to its stomachic properties. If capsules are selected they should always be followed with draughts of water or some diluent.

If for any reason the remedy cannot be given by the mouth, enemata may be adopted, and the following formula has proved satisfactory: guaiacol, gr. vij.; sweet almond oil, ʒ iss.; gum acacia, ʒ i.; water, ℥ viij.

With a view of increasing its therapeutic action its use subcutaneously has been advocated. At the International Congress of Medicine, Paris, 1890, Dr. Weill reported an experience extending over eleven years. He dwells upon the importance of using the crystals and saturating the system. The formula is as follows: Crystalline guaiacol, oil of sweet almonds sterilized, each 10 gm.; hydrochlorate of cocaine, 2 cgm.; to be dissolved in an equal quantity of water. This is kept in a dark bottle and 1 c.c. is injected into the gluteal region daily. Other methods of giving the guaiacol are adopted at the same time, and they furnish a good example of "intensive guaiacolization." Thus, for example, every night the same solution is applied to the skin over the chest, and enemata of milk, containing forty drops of the solution, are employed. The drug is also given internally. Weill advises that this treatment should be continued for several months, with intervals of eight or ten days every three weeks.

Iodoform, eucalyptol, and other similar drugs have been combined with guaiacol for use subcutaneously. Of these iodoform is the most favored.[4] The drugs are dissolved in sterilized oil and injections of iodoform, one-sixth grain, with guaiacol, one grain, are given daily.

The submucous injections have been advised in laryngeal tuberculosis; and inhalations from respirators, or from heated water, have proved of much service.

The local use of guaiacol has not been adopted to any extent, but favorable reports of its employment in this manner are met with. A five to ten per cent. solution in sterilized olive oil is used with rigid antiseptic precautions. From ten to fifteen minims are injected deeply into the diseased tissue, in two or three places, and the operation is repeated once or twice a week. In addition to its action upon the disease, guaiacol is thought to promote the formation of fibrous tissue by its astringent and congestive properties. It must, however, be used with care, as it may produce much local irritation.

The absorption of guaiacol through the unbroken skin is very rapid, and advantage is taken of this to obtain its physiological effects. Fifty to sixty minims are applied to the surface, and the part is covered with oil silk. Within fifteen minutes, the pulse relaxes, the skin becomes cool and moist, and the temperature begins to fall. The effect lasts for four or five hours. The application may be repeated night and morning according to the course of the fever. This method of employing the remedy calls for the exercise of care, as the reports of ill effects show that they generally occur when it is used in this way. On account of the rapid absorption of the drug, the fall of temperature may be rapid, descending below normal, with cold extremities, clammy skin, feeble pulse, and other indications of threatened collapse.

Guaiacol combines with the metals to form crystalline salts, but these are not of therapeutic value, owing to their being very unstable. With acid radicles it forms permanent salts and many of these have been prepared as agreeable substitutes for the crude drug. Most of them have been issued under registered trade names and freely advertised.

Guaiacol Benzoate, "Benzosol": $C_6H_4OCH_3OCOC_6H_5$. A crystalline salt in which one atom of hydrogen is replaced by a benzoyl radicle. It occurs in small colorless, tasteless, and odorless crystals, nearly insoluble in water. It contains fifty-four per cent. of guaiacol, and after administration it slowly breaks up into its constituent elements, guaiacol and benzoic acid.

It is given in doses of from five to ten grains, three times a day. It is used in all conditions in which guaiacol is indicated, and is thought to be particularly serviceable in intestinal tuberculosis and diarrhœa.

Guaiacol Carbonate, "Duotol": $(C_6H_4OCH_3O)_2CO$, a neutral, white, tasteless, odorless powder. Insoluble in water, containing ninety-one per cent. of guaiacol. In contact with the alkaline secretions of the intestines it breaks up into guaiacol and carbonic acid. The minimum dose is eight grains three times a day. Guaiacol carbonate is the most popular of the guaiacolates, probably from its being extensively advertised as duotol. It has been much used in tuberculosis and in typhoid fever, and as an antiseptic in various intestinal disorders. Reference may here be made to *cresotol* which closely resembles guaiacol carbonate, it being the carbonate of creosote, including guaiacol as well as the other constituents. It was introduced by von Leyden[5] and has been very much employed in the same conditions for which guaiacol has been used. It is a transparent liquid, odorless, but having a bitter taste. The dose at first should be five minims, and then it should be gradually increased. Doses as large as a teaspoonful have been given for a prolonged period without ill effects.[6] Professor von Leyden advised that five minims be given three times a day, and that the dose should be increased from day to day by three drops until twenty-five drops were reached; this to be continued for a few weeks and then gradually reduced to the original dose. Such a course should be repeated if necessary.

Guaiacol Cinnamate, "Styracol": $C_6H_4OCH_3OC_9H_7O$. A German proprietary medicine patented under the latter name. In the intestines it is decomposed into its two constituents, and the beneficial effects of cinnamic acid, as well as those of guaiacol, are manifested. It, however, has not been much employed.

Guaiacol piperidin, "Guaiaperol." A compound occurring in granular crystals, soluble in thirty parts of water, with a slight odor of creosote. It has been employed in the treatment of pulmonary tuberculosis and it is thought to possess the stimulating properties of piperidin in addition to the action of guaiacol. Dose: from five to thirty grains.

Guaiacol Valerianate, "Geosote." A liquid combination of guaiacol and valerianic acid, having the characteristic odor of valerian. Dose: five minims in capsules. This preparation has received much attention and is thought to have a particular value as an application in local forms of tuberculosis. It has been used in the Loomis Sanatorium for consumptives and reported upon favorably.[7]

Guaiacol salicylate; g. phosphate; g. phosphite; potassium guaiacol-sulphonate or "thiocol"; *quinine guaiacol-sulphonate,* or "guaiaquin"; *calcium guaiacol sulphonate,* or "guaiacyl"; and many similar derivatives of guaiacol have been introduced as substitutes for the pure drug. Each one is supposed to add some special therapeutic value, and although all have had some favorable mention, none has attracted much attention or proved of any special value. *Beaumont Small.*

GUAIACOL CACODYLATE is a combination of cacodylic acid with guaiacol employed by Barbary hypodermically in dose of 0.03–0.05 gm. (gr. $\frac{1}{2}$–$\frac{5}{6}$) in tuberculosis. The injection is painless, and serves as a means of introducing arsenic into the system. *W. A. Bastedo.*

GUAIACOL-ETHYL, guëthol, homocresol, ajacol, thanatol, pyrocatechin-mono-ethyl ether ($C_6H_4.OC_2H_5.OH$), is a homologue of guaiacol in which the methyl group is replaced by ethyl. It is an oily liquid, insoluble in water or glycerin, and soluble in alcohol, ether, or chloroform. It resembles guaiacol physically and physiologically, but has a greater analgesic and sedative action. It has been used topically for neuralgia, neuritis, painful joints, epididymitis, etc., in ten to fifty per cent. ointment, or hypodermically in ten-per-cent. glycerin mixture. A case of painful tuberculous cystitis, with tenesmus, was relieved by the intravesical injection of 5 c.c. (♏ lxxv.) of the ten-per-cent. glycerin preparation (Merck). Its internal dose in tuberculosis is 0.25–0.65 c.c. (♏ iv.–x.) three times a day in milk or in capsule. Von Mering believes that this preparation is better than guaiacol *W. A. Bastedo.*

GUAIAKINOL, the dibromguaiacolate of quinine, crystallizes in yellow, clinorhombic prisms. At 15° C. (59° F.) it dissolves in less than two parts of water, and on account of this solubility promises to be useful. Clinical data are wanting. *W. A. Bastedo.*

GUAIAMAR, the glycerol ester of guaiacol ($C_6H_4.OCH_3.OCH_2.CHOH.CH_2OH$), is formed by the action of anhydrous glycerin on guaiacol. It is a white, neutral, non-hygroscopic, crystalline powder, soluble in twelve parts of water, and in alcohol, chloroform, ether, and glycerin. It has a bitterish, aromatic taste, and is split in the alimentary tract into guaiacol and glycerin. George F. Butler has studied its action at the Cook's County Hospital, Chicago, and claims it to be antipyretic, diuretic, diaphoretic, and antiseptic. It stimulates the appetite and prevents gastric fermentation, deodorizes and loosens the bronchial excretions, and is a very efficient antiseptic to the alimentary or genito-urinary tract. It is less irritating than benzosol or guaiacol carbonate, though occasionally more so by idiosyncrasy. Butler recommends it in typhoid fever, tuberculosis, bronchitis, broncho-pneumonia, chronic cystitis, gonorrhœa, and the summer diarrhœas of children. Its dose is 0.2–1 gm. (gr. iij.–xv.). Locally, with belladonna and mercurial ointments, he applies it to rheumatic joints; and, with balsam of Peru and zinc ointment, to bedsores. *W. A. Bastedo.*

GUAIASANOL, di-ethyl-glycocoll-guaiacol hydrochloride, was introduced by E. Einhorn and Hütz as a soluble form of guaiacol. It crystallizes in white prisms, having a faint odor and a saline, bitter taste. It is neutral to litmus, and is freely soluble in water from which it is precipitated as a basic oil by the alkaline carbonates. Guaiasanol liberates guaiacol in the alimentary tract, and is used both externally and internally for the same purposes as guaiacol. Experiments show that it is without unpleasant effects in daily dosage of 3–12 gm. (gr. xlv.–clxxx.). It may be used hypodermically, and in two-per-cent. solution is unirritating to wounds.
W. A. Bastedo.

GUARANA.—(Pronounced *Gwaw-rah-nah'.*) "A dried paste, consisting chiefly of the crushed or pounded seeds of *Paullinia Cupana* Kunth (fam. *Sapindaceæ*)" (U. S. P.). This is a climbing shrub, native of the hottest parts of South America, but the seeds are obtained wholly from cultivated plants.

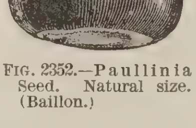

FIG. 2352.—Paullinia Seed. Natural size. (Baillon.)

The genus contains upward of one-hundred and twenty species, and its members are rich in saponin, also contained in guarana, on account of which parts of several of them are used as fish-poisons.

The guarana plant is very extensively cultivated, especially upon the banks of the Itenez River, a southern tributary of the Madeira. It is grown to stout stakes or poles and the plantation resembles an ordinary vineyard. The panicles of small white flowers are succeeded by fruit clusters looking not unlike large bunches of immense grapes. When ripe, the yellow fruit splits into three husks and the seeds are lost. They are gathered just previous to this time and the seeds are shelled and washed. The seed is large (1 cm. in diameter), globular or spheroidal, with a flattened base, and a slightly pointed apex. Its surface is dark-brown and very shiny, excepting the large chalaza at the base, which is light-colored, and, before it is disturbed, covered with a large aril. It is exalbuminous and entirely filled by the large fleshy embryo.

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[1] F. Enke: Experimentelle und histologische Untersuchungen, etc., Stuttgart, 1880.

[2] Prof. Max Schueller: Eine neue Behandlungsmethodeder Tuberkulose, besonders chirurgischen Tuberkulosen, Wiesbaden, J. F. Bergmann, 1891.

[3] The London Lancet, 1891, vol. i., p. 993.

[4] La Semaine Médicale, March 4th, 1891. British Medical Journal, 1895, vol. ii., p. 1488; 1891, vol. ii., p. 1040.

[5] Charité-Annalen, Berlin, 1897.

[6] The London Lancet, 1898, vol. i., p. 222.

[7] New York Med. Journ., April 2d, 1898. Journ. Amer. Med. Assn., vol. xxxi., p. 821.

In general appearance and structure it may be described as a small horse-chestnut. After shelling, the seeds are lightly roasted, by which the testa is loosened. The latter is then broken off and winnowed out, and the kernels are coarsely broken up in a wooden mortar and with a wooden pestle. Just enough water is added to form an adhesive mass. This mass is then moulded by hand into cakes, balls, or, more commonly into sausage-shaped rolls, six to ten inches in length by one or two in diameter. The drying of these is the most delicate and critical part of the operation. It is conducted by artificial heat, in specially built houses, great care being taken to avoid a disagreeable flavor from the smoke or from the subsequent development of some variety of mould through imperfect or unequal drying. Adulteration occurs only occasionally. It consists in making various additions—usually tapioca starch—to the mass before it is subjected to the drying process.

As regards the home consumption of guarana, it is the exact equivalent of tea or coffee, except that it is grated off and taken suspended in cold water. It is the staple beverage of millions of people. Its excessive habitual use brings on nervous disorders similar to those from other caffeine-containing beverages, and ending in a kind of palsy.

Description.—In subglobular or elliptical cakes or cylindrical rolls, hard and heavy; outer surface somewhat shortly nodular, smooth, slightly lustrous, deep chocolate-brown; rather brittle, the fracture uneven, often fissured in the centre, of a deep flesh color or pale reddish-brown, showing numerous coarse, angular, lustrous fragments of seeds partly invested with blackish-brown integuments; odor slight, peculiar, a little resembling that of chocolate; taste very astringent, somewhat bitter, afterward sweet, especially when chewing is followed by the taking of a swallow of water.

Composition.—Guarana stands at the head of caffeine-yielders, containing four or five per cent. A quarter of its weight is tannin, and there are starch, saponin, resin, and small amounts of fixed and volatile oil. It should not yield more than two and one-half per cent. of ash. It should be remembered that the domestic value of guarana depends largely upon its flavor. Many lots defective in this particular are exported for medicinal use and are not necessarily inferior for this purpose. At the same time, adulterated lots are undoubtedly manufactured especially for such export, but only rarely.

Action and Medicinal Use.—Because of its tannin, guarana is to be compared rather with tea than with coffee. Caffeine is elsewhere so fully treated that its action cannot be here discussed.

As the contained dose of tannin is a small one, it is, in fact, a mode of giving caffeine, and little or nothing more. Its principal clinical reputation lies in its value in nervous and sick headaches, of which there is considerable evidence. It has been the foundation of several widely known secret remedies for these afflictions.

The powdered drug can be given in gram doses or more, repeated once an hour, until the headache is relieved, or until several doses have been given. The fluid extract (*Extractum Guaranæ Fluidum*, U. S. P.) is rather neater, and of the same theoretical strength. Milk is a good vehicle for either. *Henry H. Rusby.*

GUARANINE.—A name applied to *caffeine*, when derived from *guarana*. *Henry H. Rusby.*

GUERNSEY AND THE CHANNEL ISLANDS.—The Channel Islands, comprising Jersey, Guernsey, Alderney, Sark, and several smaller rocky islets, are situated in the bay of St. Michael, off the coast of Normandy, and lie between the latitude of 49° 10′ and 49° 42′ North and 2° 2′ and 2° 40′ West longitude. Guernsey and Jersey are the only two islands which require consideration as health resorts, and their claim as such is based upon the mild sunshiny nature of their climate, especially in the late autumn and winter. "Recent statistics show that Jersey receives more sunshine than any other part of the United Kingdom." In these islands "camelias and rhodendrons flower in the open in February, frost is rare, and lasting snow unknown."

St. Helier's in Jersey and St. Peter's Port in Guernsey are the chief towns. The following table gives the climatic characteristics of Guernsey, which are practically the same as those for Jersey.

Climate of Guernsey and Jersey. Means for Ten Years. Height Above Mean Sea-Level, 180 Feet.

	January to March.	April to June.	July to September.	October to December.	Year.
Temperature—					
Mean average.........	43.7° F.	53.0° F.	60.5° F.	48.8° F.	51.5° F.
" daily range.....	7.6	10.8	10.9	7.6	9.2
" of warmest.....	47.5	58.4	66.0	52.6	56.1
" of coldest.......	39.9	47.6	55.1	45.0	46.9
" relative humidity	87%	83%	83%	86%	85%
Precipitations—					
Average in inches....	7.53	5.82	6.96	12.22	32.53
Wind—					
Prevailing direction..	....	....	....	....	W. and S. W.
Weather—					
Amount of sunshine...	304 hrs.	665 hrs.	648 hrs.	247 hrs.	1864 hrs.
Mean cloud...........	7.1%	6.0%	6.6%	7.2%	6.6%
Rainy days............	47	34	39	59	179

From this table we see that the general climate of these two islands (Jersey and Guernsey) is a mild, moist, marine one. The diurnal range of temperature is small, and there is an average of five hours of daily sunshine. Of the total rainfall one-fourth occurs in the months of October and January. March and April are considered the most trying time of the year on account of the north-easterly winds.

Of course the islands are exposed to the winds from all directions, which, coming from the ocean, are moist and salt-laden. The prevailing winds are westerly and south-westerly, especially the latter.

The following table of yearly averages of wind is given for Guernsey, for the period from 1845 to 1862, inclusive:

Northeast wind prevailed on 100 days.
Southwest wind prevailed on 104 days.
Northwest wind prevailed on 110 days.
Southeast wind prevailed on 51 days.

The drinking-water is obtained, for the most part, from wells. The drainage at St. Helier's and St. Peter's Port is by sewers into the sea.

The therapeutic effects of this climate arise from its mild sunshiny nature and its marine atmosphere. Elderly persons with low vitality and those with bronchial affections derive benefit from it. It is also of especial value for delicate scrofulous children and those of rachitic tendencies. It is unfavorable, on account of its moisture, for rheumatism, neuralgia, and renal diseases. Those with a tendency to respiratory troubles should not remain after the end of February. The Channel Islands are reached by boat from Southampton, Weymouth, or Plymouth in from six to ten hours, or from St. Malo or Granville, France, in two or three hours.

From a personal visit to Jersey the writer can testify to the delightful scenery of the island, both land and water, and the charm of the lovely drives through the winding roads, bordered by luxuriant vegetation. The air is fresh and invigorating and the sunshine most brilliant.

The writer desires to express his indebtedness in the preparation of this account of Guernsey and Jersey to "The Climates and Baths of Great Britain," by the Royal Medical and Chirurgical Society of London, 1895.

Edward O. Otis.

GUINEA WORM. See *Nematodes.*

GUINORAL (Chinoral) is an oleaginous, very bitter liquid, containing quinine and chloral. It is used as a hypnotic in doses of 0.5–1 gm. (gr. viij.–xv.), and also as an antiseptic. *W. A. Bastedo.*

GUM ARABIC.—Acacia. *Gum Acacia. Gum Senegal.* "A gummy exudation from Acacia Senegal Willd. (fam. *Leguminosæ*)" (U. S. P.). In roundish tears, often an inch or more in diameter, transparent, except for the whitish fissures, of a glassy fracture, ranging from nearly colorless to a deep reddish-yellow, nearly tasteless and odorless, wholly soluble in two parts of water, to form a thick mucilage of a faintly acid reaction. The presence of starch in powdered acacia is detected by a blue color on the addition of iodine, that of dextrin by a red color. A pure solution will not be affected by neutral lead acetate.

This gum was formerly yielded by other species of acacia, notably *A. vera* Willd., and the very finest gum of commerce, now scarce and high, still proceeds from this species. It is chiefly in smaller tears, which are more brittle and broken, and less translucent and glassy, owing to the much more numerous fissures. Both species are small thorny trees of northern Africa, *A. vera* more abundant in the eastern, *A. Senegal* in the western districts. The gum is a decomposition product from cellulose and is more abundantly produced by unhealthy trees. It exudes from natural fissures and artificial incisions. Gums practically equivalent to acacia are produced by species in related genera. An excellent article is produced by species of Prosopis, growing in the southwestern United States, and known as Mesquit Gum, but the supply is too irregular to be utilized. The varieties of acacia are now little known by the locality-names formerly applied to them, the grading being done almost wholly by number, the quality depending upon whiteness and solubility. The pure gum consists wholly of compounds of arabic acid with potassium, calcium, and magnesium. Acacia has no physiological action, except that of a mechanical demulcent. Its pharmaceutical uses, as an excipient, for emulsionizing, and for suspending insoluble substances or those the acridity of which it is desired to mitigate, are very numerous and important.

Henry H. Rusby.

GUMMA. See *Syphilis.*

GUMS. See *Active Principles.*

GUNSHOT WOUNDS.—No chapter in surgery has undergone such radical changes as that pertaining to gunshot wounds in war. The changes have been coincident with the introduction of antisepsis and the new armament in hand weapons which employ armored projectiles. The changes with reference to the latter concern the military surgeon mostly. His *confrères* in civil life will continue to observe gunshot injuries, as far as their mechanical effects are concerned, as formerly. The wounds of this class that come under his care are mostly from pistol shot, the missiles of which are made of soft lead, are propelled at comparatively low rates of speed, and show a marked tendency to lodge and to deform upon impact with resistant structures.

In order to obtain a correct understanding of gunshot wounds a consideration of the implements which are concerned in their production is necessarily of much importance.

Portable Firearms.—Arms of this class are often referred to as portable hand weapons. They include the firearms that are carried by hand in contradistinction to the larger guns of the artillery class. They are the pistol, shotgun, the smooth-bore muzzle-loading musket, and the rifle. A knowledge of the development of portable firearms as a whole, and of ballistics in particular, is indispensable to a correct appreciation of the subject of gunshot injuries. For all practical purposes a study of the evolution of the military rifle as it presents itself to the military surgeon will be quite sufficient to a general understanding of the subject.

Military Rifle.—A study of the guns concerned in the evolution of the small arms which culminated in the present military rifle deals with: (1) smoothbores like the flintlock and musket; (2) the percussion-cap, muzzle-loading rifle; (3) the breech-loading rifles; and (4) the breech-loading magazine rifle with small calibre.

1. The smoothbores of the first class are represented by the old-time flint lock and later by the Spanish musket, whose calibre varied from .63 to .75. They fired a bullet made of soft lead weighing from 465 to 555 grains; the explosive was loose black powder in charges varying from 270 to 345 grains. The projectile was spherical in shape, with an initial velocity of from 540 to 690 foot seconds, while the maximum effective range was never more than 350 yards.

Our first three wars—the Revolutionary War, the War of 1812–14, and the Mexican War—were fought with weapons represented by this class. As implements of war they were considered very effective in their day, and yet at no time could the best type of them be loaded at greater speed than thrice per minute.

2. The percussion-cap, muzzle-loading rifles were first used in the Italian War of 1859; they were subsequently used in our Civil War, and in all European wars up to 1866. Instead of igniting the powder charge by means of a taper as in the old match-lock, or by the spark of a flint as with the flintlock, it made use of a small cap containing a detonating substance. The cap was placed over a hollow piece, the cavity of which led to the powder charge. The latter was ignited by causing the hammer to strike the cap.

In the earlier patterns of these guns there was so much escape of the powder gases through the inequalities between the ball and sides of the weapon, with consequent loss of energy, that the practice of slightly reducing the calibre of the gun as compared to that of the diameter of the ball, and grooving the interior of the former, was resorted to. This was done to insure greater accuracy in the fit of the ball. In order to allow more of the surface of the ball to come in contact with the barrel, it was elongated. The fit of the ball was so tight that it was necessary to drive it down with a ramrod and hammer, both of which formed part of the equipment of the soldier at that time. This gave greater exactness of fit between the ball and barrel and both added to the energy and extended the range by retaining the projectile a trifle longer in the barrel, while the explosive was generating a greater volume of gas. It was noticed that the elongated bullet fired from such a gun was apt to tumble or lose its balance, and this was overcome in a measure by giving the grooves in the barrel a spiral turn, at the rate, in the earlier guns, of one complete turn in about seventy-eight inches. This added much to the stability of the bullet, keeping its point foremost for a longer time in its flight, thereby adding to its range and effectiveness. This principle in ballistics should be specially remembered, aside from the development in the use of explosives, because it is really the initial point in the great strides that have been made in the effectiveness of bullets. The act of loading with the ramrod and hammer was very laborious. To overcome the difficulty Delvigne, a French army officer, hollowed out the base of the projectile next to the powder. The expanding gases pressed the sides of the cup so formed into the metal grooves in the barrel, thus causing the bullet to take the rifling. Later, in 1847, Captain Minié made a still further advance by suggesting the use of an iron disc in the cup. The harder metal being forced against the sides of the cup insured greater expansion than the gases alone, so that the accuracy of fit between the ball and the barrel was more completely secured. The so-called Minié rifle used in the Crimean War, and our own Springfield used in the Civil War, were loaded with such bullets. The following were the principal features of the Minié rifle which correspond with those of our earlier make of the Springfield rifle.

Minié-Rifle, 1851 to 1866.

Weight with bayonet	10 pounds 8¾ ounces.
Diameter of bore	.702 inches.
Number of grooves	4
Twist	1 turn in 78 inches.
Diameter of bullet	.690 inch.
Weight of bullet	680 grains.
Charge of powder	150 "

Sighted for 100 to 1,000 yards.

The old Minié ball formed the section of a cone, so that the accuracy of fit in the barrel was confined almost entirely to the base of the bullet. The resulting inequality of its different sectional areas disturbed the balance of the projectile to such an extent that its stability in flight was soon lost. Instead of rotating on its long axis, it was apt to tumble or to commence to rotate on its short axis, at right angles to its line of flight. To overcome this difficulty the body of the projectile was made cylindrical; the base was cupped, the metal stopper was replaced by a boxwood plug, and the head was made hemispherical instead of conical in shape. This was the missile used in the Enfield of the English foot troops till 1871, as well as in our old pattern Springfield rifle, which formed the armament of our infantry from 1855 to 1873. The calibre of the latter at this time was reduced to .58, its weight to 500 grains, and the charge of powder to 80 grains.

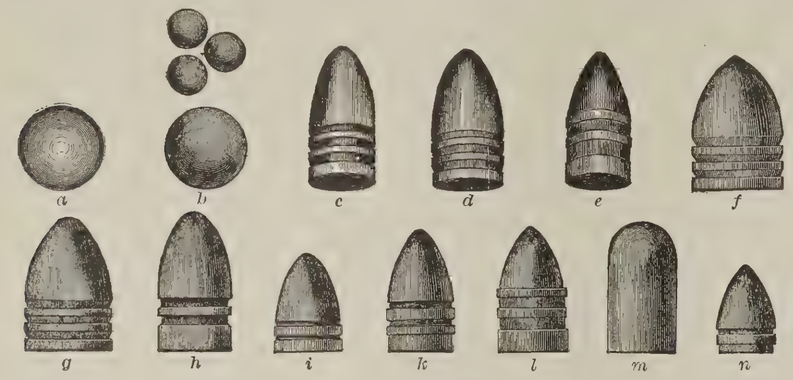

FIG. 2353.—Different Kinds of Projectiles. *a*, United States round musket ball, calibre .69, weight 387 grains; *b*, buck and ball, calibre .69, weight of ball 387 grains; *c*, Springfield rifled musket ball, calibre .58, weight 500 grains; *d*, Enfield rifled musket ball, weight 450 grains; *e*, Austrian rifle ball, weight 460 grains; *f*, elongated bullet, calibre .71, weight 675 grains; *g*, elongated bullet, calibre .69, weight 760 grains; *h*, elongated bullet, calibre .577, weight 517 grains; *i*, Burnside rifle bullet, calibre .54, weight 400 grains; *k*, Spencer rifle bullet, calibre .56, weight 434 grains; *l*, Sharp's carbine ball, calibre .52, weight 450 grains; *m*, Green's rifle ball, calibre .53; weight 575 grains; *n*, Colt's army pistol bullet, weight 207 grains.

3. Breech-loaders. The great desire of military men to increase the rapidity of fire led to the introduction of breech-loaders. Although loading by the breech had been practised since the reign of Henry VIII., the mechanism of the earlier weapons was so uncertain and clumsy that they were not used by armies until about 1866, when the Germans demonstrated the superiority of their needle gun in the Austro-Prussian war.

In 1866 the United States Government modified the muzzle-loading Springfield rifle by adding the breech-block which permitted loading by the breech. It was at this time that the calibre was reduced to .50. In 1873 the calibre of this same weapon was further reduced to .45, the twist was shortened to 1 turn in 22 inches, the charge was reduced to 70 grains of black powder, while the weight of the bullet was still retained at 500 grains. These improvements increased the velocity at the muzzle to 1,301 foot seconds, and the maximum effective range to 2,000 yards. Compared to the effectiveness of a generation before the advancement was certainly very great, yet those who marvelled at these rapid strides in the manufacture of the engines of war were hardly prepared for the rapid advances that were soon to follow.

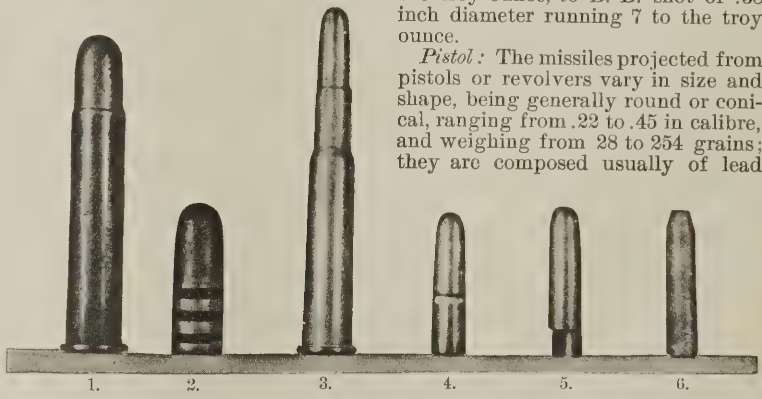

FIG. 2354.—Projectiles for Rifles. 1, Complete cartridge .45 calibre Springfield rifle; 2, projectile of cartridge .45 calibre Springfield rifle, 480 grains; 3, complete cartridge .30 calibre Krag-Jörgensen rifle; 4, steel-jacketed projectile, Krag-Jörgensen rifle, 220 grains; 5, steel-jacketed projectile, Krag-Jörgensen rifle; 6, the lead nucleus of Krag-Jörgensen projectile.

4. *Magazine Breech-loading Rifles, with Reduced Calibre.* The modern tactics in war involve rapidity in movements, and with these rapidity in fire. The latter led to the introduction of the magazine rifle, an arm that carries a reserve of ammunition in some part of its mechanism. Increased expenditure of ammunition with the new arm necessitated a greater number of rounds per man. But the soldier was already loaded to the maximum of weight, so that the number of rounds could be increased only by reducing the calibre and thereby the weight of the bullet. The calibre of military rifles has thus been reduced as far as .26, and the weight of their projectiles as low as 156 grains, thereby nearly doubling, for the same weight, the number of rounds that soldiers usually carried. This reduction in calibre of the rifle increased the difficulty incident to fouling, *i.e.*, to the lodgment of the unconsumed residue of the old black powder on the inner wall of the barrel, and eventually led to the introduction of so-called smokeless powders that leave little or no residue, and that possess the further advantage of conferring upon the projectile a greater initial velocity (owing to the fact that the gases which they emit are relatively more voluminous than those resulting from the ignition of the old black powder). This increase in velocity added quite a complication. The lead bullet instead of keeping point on, tumbled, to prevent which, a shorter twist was given to the grooves in the barrel. Instead of one complete turn in 22 inches, the twist was shortened to 1 in 10 inches. The old lead bullet became refractory under the bidding of such a sharp turn. Instead of following the new twist it was apt to strip through the barrel without properly revolving, a difficulty which was obviated by coating the lead with some harder metal.

Generally speaking, the classification of gunshot wounds is based on the character and size of the missiles that caused them.

Shotgun: The missiles from ordinary shotguns vary from fine round lead projectiles running from 2,020 to the troy ounce, to B. B. shot of .38 inch diameter running 7 to the troy ounce.

Pistol: The missiles projected from pistols or revolvers vary in size and shape, being generally round or conical, ranging from .22 to .45 in calibre, and weighing from 28 to 254 grains; they are composed usually of lead hardened with antimony in the proportion of 95 parts of the former to 5 parts of the latter. The missiles from the remainder of the hand weapons should be divided into two classes, viz., those of the smoothbore guns and those of the rifles. Those of the latter should be further divided into the lead and jacketed projectiles.

Smoothbores.—The missiles of the smoothbore guns were round, made of soft lead, ranging from .68 to .75 in calibre, and weighing from 465 to 555 grains.

Lead projectiles for rifles were conoidal in shape and composed of lead, generally hardened with antimony; they ranged from .45 to .71 in calibre, and weighed from 387 to 675 grains.

Jacketed projectiles for rifles are made of a lead core enclosed in a mantle of harder metal, like copper, German silver, white metal, or cupro-nickel steel—generally of the latter. Their calibre is much smaller, .26 to .31, and their weight ranges from 156 to 244 grains.

TABLE I.—BALLISTIC DATA OF THE NEW SMALL-CALIBRE RIFLES NOW ADOPTED BY DIFFERENT NATIONS.

Army.	RIFLE.		BULLET.				Smokeless powder, grams.	Muzzle velocity, metres.	Muzzle energy in kilogram-metres.	POINT-BLANK RANGE.		Rounds in magazine.
	Designation.	Calibre, mm.	Calibre, mm.	Weight, grams.	Length, mm.	Structure, core, and casing.				Infantry, metres.	Cavalry, metres.	
Argentinian	Mauser, 1891	7.65	7.89	13.7	30.7	Lead, cupro-nickel, steel	2.64	635	....	558	640	
Austrian	Mannlicher, 1888–1890	8.0	8.19	15.8	31.8	Hard lead, steel case	2.74	620	309.6	466	548	5
British and Canadian	Lee-Metford, 1893, Mark II.	7.7	7.89	13.9	31.5	Hard lead, cupro-nickel	1.97	630	320.4	503	687	8
Brazil, Chili, Mexico, Spain	Mauser, 1894–1895	7.0	7.22	11.3	30.9	Hard lead, cupro-nickel, steel	2.89	720	275.8	622	695	5
Danish	Krag-Jörgensen, 1889	8.0	8.19	15.4	30.0	Lead, cupro-nickel	2.19	620	283.2	....	....	5
French	Lebel, 1886–1893	8.0	8.19	15.0	30.0	Hard lead, cupro-nickel	2.79	630	305.4	515	608	8
German	Mauser, 1888	7.9	8.10	14.7	31.25	Hard lead, cupro-nickel, steel	2.74	640	286.1	530	594	5
Italian	Mannlicher-Carcano, 1891	6.5	....	10.5	30.5	Hard lead, cupro-nickel	1.87	700	262.2	....	....	5
Russian	Kapit-Mozin, 1891	7.62	7.79	13.68	30.2	Hard lead, cupro-nickel	1.97	620	271.6	512	580	5
Roumanian	Mannlicher, 1893	6.5	6.70	10.34	31.5	Hard lead, cupro-nickel, steel	2.44	720	272.9	....	....	5
Swiss	Schmidt-Rubin, 1889	7.5	8.10	13.7	31.7	Hard lead, steel point, paper jacket.	1.94	600	251.4	507	590	12
Turkish	Mauser, Belgian, 1890	7.65	7.89	13.8	30.8	Lead, cupro-nickel	....	652	303.4	515	608	5
United States	Krag-Jörgensen modified, 1892.	7.62	7.82	14.26	30.63	Hard lead, cupro-nickel, steel	2.09	610	275.4	515	584	5

Aside from the foregoing there are other missiles and substances concerned in the production of gunshot wounds. These are principally employed in warfare, and they may be considered under the following heads:

LARGE PROJECTILES OR THEIR FRAGMENTS.—These are the large solid shot, and large hollow shells provided with a charge of some explosive used to generate expansive gases that break the projectile into fragments at or about the time of impact. The large solid shot from cannons is used to penetrate armor and to demolish fortified positions. The hollow shells are used to develop positions, and this is done by observing the distance at which bursting occurs, thereby establishing the range

Shrapnel.—The use of shrapnel is largely restricted to the artillery arm in war, a typical example of which is found in the Frankford Arsenal Shrapnel in use by our field artillery. It is a hollow steel projectile composed of a head, body, and base. The head contains 2¾ ounces of black powder; the body holds 162 lead and antimony balls, 41 to the pound, disposed in circular layers and held by cast-iron separators. The shell and separators are deeply grooved to invite separation into corresponding fragments at the time of bursting. The head is provided with a fuse which is so timed that explosion is made to take place at any interval of 60 yards or one-sixth of a second. As many as 202 missiles have been counted after an explosion. The maximum effective range of this projectile is 7,000 yards. The flight of the fragments represents an extending cone for 400 or 500 yards, the diameter of which is 30 feet at a distance of 25 yards from the place of bursting.

Canister.—Canister, sometimes called caseshot, is a projectile not unlike the shrapnel. It is cylindrical in shape, the walls of the cylinder being composed of a thinner metal and enclosing 200 or 300 round lead balls hardened by antimony. The projectile is ruptured close to the muzzle at the moment of discharge by the force of the explosion in the gun, and not by the liberation of gases from an explosive within the shell, as occurs in the case of the shrapnel. Such a projectile is of use only at close range, from 300 to 500 yards, depending upon the calibre of the gun.

EXPLOSIVES.—The modern advance in conferring extended range, velocity, and penetration upon projectiles, is due to the development in the use of explosives. They are employed not only to propel missiles into space, to explode projectiles, etc., but also to explode mines, fugases, and bombs in offensive and defensive warfare; and, by evil-doers, in the destruction of life and property. A consideration of these various chemicals and the manner of their action in the creation of wounds naturally falls under the subject of gunshot wounds. Among the more familiar explosives may be mentioned: gunpowder, fulminates, and certain chemical compounds.

Gunpowder.—Gunpowder is the most ancient of all explosives. It is generally referred to as black gunpowder to distinguish it from certain chemical compounds which vary in color from brown to black and which are usually designated as smokeless powders. The composition of black gunpowder has remained almost constant for centuries, viz., saltpetre, charcoal, and sulphur in percentages of something like 75, 15, and 10 in the order named. In this mixture saltpetre furnishes the oxygen, carbon supplies the fuel, and sulphur promotes the rapidity of the explosion. Gunpowder explodes when

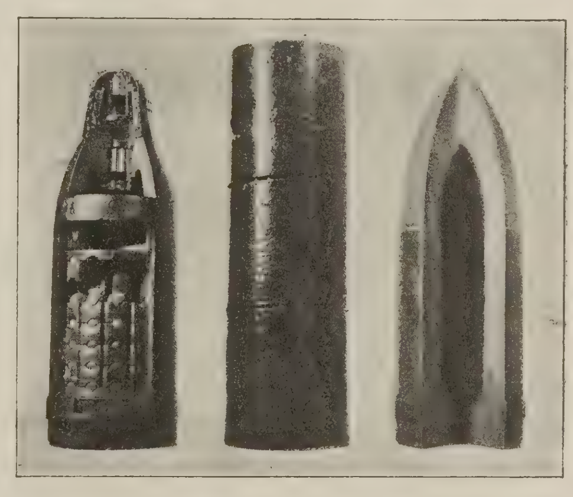

FIG. 2355.—Larger Projectiles. Shrapnell (1), Canister (2), Shell (3), Used with 3.2 inch Breech-Loading Rifle-Filled Batteries.

heated to 700° F. The volume of the gas which it generates occupies 250 times the bulk of the charge employed. It is this resulting expansion which serves to propel the missile from a gun barrel and which confers upon it such velocity as to enable it to penetrate tissues, thereby causing gunshot injuries. The temperature of the flame which is noticed at the time of ignition has been variously estimated at 2,000° to 4,000° F., a fact which doubtless has had much to do with spreading the old-time notion of the searing and burning effects of bullets upon the tissues. The chemical results of the disintegration of gunpowder are 32 per cent. of gaseous products, and 68 per cent. solid residue. The gases generated are carbonic oxide, carbonic acid, and nitrogen, with some aqueous vapor. The pressure which the gaseous products exert on the gun barrel is said to be more than 4,000 atmospheres for 1 gm. of the powder ignited.

Fulminate Powder.—Fulminate of mercury is principally used as a detonator in exploding guncotton and other explosives, and also in charging percussion caps and primers. The volume of gas generated for the amount of substance is relatively very large. Disintegration of the substance into gases is so rapid and the pressure exerted by the sudden displacement of air is so violent in all directions that the term detonate has been employed to characterize the explosion. Thus we say that it detonates instead of saying that it explodes. The gases formed are carbonic acid. nitrogen, and vapor of mercury. As an example of the tremendous force exerted by the sudden displacement of these gases, it may be stated that in the attempt to assassinate the French Emperor in 1858, three tubes, each containing two ounces of the fulminate, were exploded, and from these explosions there were produced 511 wounds upon 51 persons.

Smokeless Powders.—So called because they emit very little smoke as compared to black gunpowder; and unlike the latter they exhibit neither flame nor burning at the time of explosion. As to their exact composition it may be stated that they are secret compounds. In a general way we know that they are composed of guncotton (cordite), dynamite, or picric acid (melinite). Some of the smokeless powders that have been analyzed show ninety-four per cent. guncotton, five per cent. nitroglycerin, one per cent. castor oil. Melinite is made up of picric acid with collodion jelly. Aside from those composed of guncotton or picric acid as a base, there is a class known by various names, such as roburite, rock-a-rock, hellofite, securite, etc., which explode only upon mixing two or more substances, as chlorinated dinitrobenzole with ammonium nitrate, chloride of potassium impregnated with liquid hydrocarbon, naphthalin, phenol, or benzin in fuming nitric acid, etc.

The causes that influence the character of gunshot wounds may be treated under the following heads:

MECHANICS OF PROJECTILES.—The character of gunshot wounds has been as much influenced by the discovery of high explosives as it has by the perfection attained in the manufacture of firearms. These two essential particulars involve a study of the motion of bullets in flight in order that the lesions inflicted on impact may be properly interpreted. It is only with such knowledge that penetration, smashing, and mutilation of tissues can be explained in a given case.

Trajectory.—The trajectory of a projectile is the curve which it describes in space from the muzzle to the first point of impact.

Velocity.—In speaking of the flight of a projectile in space we employ the term velocity, and this in turn is usually divided as follows:

1. Initial Velocity.—The initial velocity of a projectile is its rate of motion as it issues from the muzzle of the gun, that is, the number of feet it passes over in one second of time, known in mechanics as the foot-second system. For revolvers this rate is seldom more than 700 foot seconds, whereas, with the more perfect hand rifles, it is as much as 2,400 foot seconds.

2. Remaining Velocity.—The remaining velocity is the rate of speed which a bullet still possesses at any given point in its flight. Thus, for instance, the projectile that may issue from the muzzle of a given weapon at the rate of 1,800 foot seconds, is so influenced by the gravity of the earth and friction against the air that its flight is impeded in proportion as the distance from the gun increases, so that, on reaching a distance of 500 yards, the velocity, instead of being 1,800 foot seconds, will have fallen to 900 foot seconds.

Energy.—The energy of a bullet has always been of interest to surgeons, because its power to do work is measured by the energy which it possesses of overcoming resistance at the moment of impact. In olden times when the manufacture of firearms was imperfect and our knowledge of explosives was restricted to black gunpowder, we sought to increase the energy of a projectile by increasing its mass, but to-day superior knowledge in manufacture and modern advance in the use of explosives enable us to attain the same end by increasing the velocity. The latter method is more effective in this, that formerly if we chose to double the energy of a projectile we doubled its mass, whereas to-day we double the velocity and thereby increase the energy fourfold. The following table illustrates the two velocities, and the energy of our present service bullet and that of the Springfield rifle at varying ranges up to 2,000 yards.

The velocity and energy of the projectiles of the two weapons at different ranges are as follows:

TABLE II.—VELOCITY OF THE PROJECTILES OF THE TWO GUNS.

Name and calibre of weapon.	Initial velocity.	500 yards.	1,000 yards.	1,500 yards.	2,000 yards.
Springfield, calibre .45	1,301	873	676	531	429
* Experimental Springfield, calibre .30	2,000	1,103	804	627	495

ENERGY OF THE PROJECTILES (IN FOOT POUNDS).

Name and calibre of weapon.	Initial velocity. F. S.	Weight, grains.	Muzzle.	500 yards.	1,000 yards.	1,500 yards.	2,000 yards.
Springfield, calibre .45	1,301	500	1,879	846	507	313	204
* Experimental Springfield, calibre .30	2,000	220	1,954	594	315	192	120

* Which corresponds in ballistic value to the Krag-Jörgensen rifle.

Rotation of Bullets.—As a bullet issues from a gun two motions are imparted to it: one of translation and one of rotation. The former is due to the pressure of the powder gases which impel it onward into space, the latter is either accidentally or purposely given. In the first instance we have the rotation that was observed with old spherical bullets from smoothbores, in which the direction of the rotation was marked by the last point of contact of the projectile with the inside of the gun barrel. The axis of rotation was always at right angles to the line of flight, and its rapidity was always variable. In the latter instance we have the rotation that is purposely conferred by the gunmaker in grooving the inside of the barrel with from two to five or six spiral grooves, the direction of which, usually to the right, is followed by the bullet as it issues in a rotatory motion from the muzzle. This rotation is purposely conferred on elongated bullets to keep them moving point on. The axis of rotation with them is parallel to the line of flight, and not at right angles, as it is with spherical bullets. The velocity of rotation is determined by the sharpness of the twist in the barrel. In our present service rifle the twist describes one complete turn in about ten inches.

Shape and Density of Projectiles.—The character of a gunshot wound is often influenced by the shape and density of the missile that inflicts it. The tendency with the old spherical ball from smoothbore guns upon impact with resistant bone was to smash or comminute the bone at the point of impact, doing little or no damage to the shaft above or below. As the bullet was composed of soft lead, a resistant bone usually caused it to mushroom or otherwise lose its shape, thus adding to the amount of comminution. Later, as the rifle came in vogue, the cylindro-conoidal bullets were introduced. The effect of these wedge-like missiles was to penetrate and produce splintering above and below the point of impact, thus causing displacement of larger fragments of bone beyond the foyer of fracture. The deformation of the leaden missile added to its sectional area, thereby magnifying the destructive effects. The tendency to penetrate was still further increased by the employment of jacketed projectiles. The hard envelope preserves the shape of the projectile, so that the additional amount of destruction consequent upon deformation, so often noticed with the old leaden bullet upon impact with resistant bone, is seldom noted. The tendency with it is to perforate and fissure bone rather than to cause extensive comminution.

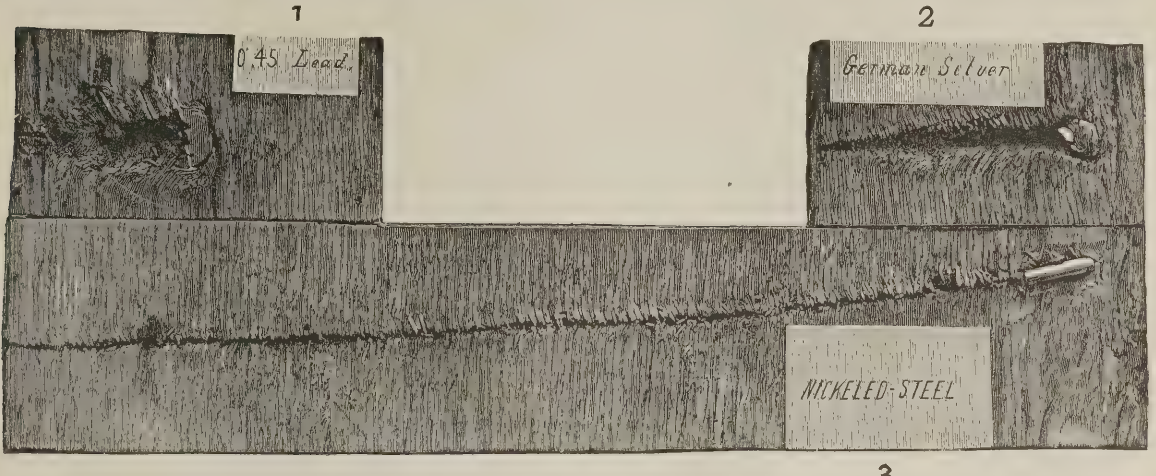

FIG. 2356.—Shows the Penetration in Hard Oak, against the Grain, Three Feet from the Muzzle, of the following Projectiles: 1, ."45 calibre leaden projectile, weight, 500 grains; I. V., 1,300 f. s., 3."2. 2, ."30 calibre German-silver jacketed projectile, weight 220 grains; I. V., 2,000 f. s., 5."3. 3, ."30 calibre nickel-steel jacketed projectile, weight 220 grains; I. V., 2,000 f. s., 19."5. The latter was not deformed.

The introduction of the modern rifle of reduced calibre at a time when the world was at peace rendered experimental evidence necessary to show what might be the difference in destructive effects between it and the older weapons of larger calibre and lower velocities. At no time in the history of firearms has the subject of the mechanical effects of projectiles been so thoroughly studied as it has during this so-called experimental stage. The experiments of military surgeons in the different countries of the civilized world and their studies of the injuries caused by gunshot have been conducted in such a thorough fashion, and they have entered so minutely into the mechanics of projectiles generally, that a report of what has been learned cannot fail to be of practical value to the civil as well as to the military surgeon.

Our knowledge of the rifles of reduced calibre propelling armored projectiles dates from the publication of Professor Hebler's pamphlet in 1882. In his original monograph Hebler claimed certain advantages for the reduced calibre rifle, among which were the following: (1) lighter ammunition; (2) flatter trajectory and greater dangerous space; (3) less deviation by wind; (4) less recoil; (5) greater penetration; (6) greater accuracy; (7) the wound produced, while being sufficient to disable, is much more humane.

Some of these advantages were so apparent that they could not be refuted, while the others required the proof which could be obtained only by experiments or by observation of the actual conditions in the field.

That the ammunition is lighter there is no doubt, since a soldier who carries 100 rounds of the older ammunition can carry for the same weight about 180 of the new ammunition. That the trajectory of the new rifle is flatter, and that the dangerous space is consequently greater, is also apparent, since those versed in ballistics have shown us that the point-blank range of the older gun of the Springfield pattern is 300 yards, while that of the Krag-Jörgensen rifle, our present service gun, is about 570 yards.

The advantage of less recoil is perfectly apparent to any one who will shoot the two last-named weapons one after the other. The remaining advantages claimed by Hebler were not so readily determined. Greater accuracy and less deviation by wind had to be determined by comparison at target. Although the small-bore guns and ammunition have been perfected very much of late, it is yet a fact that, in the remote ranges, the smaller and lighter projectile is more influenced by wind than the heavier and larger leaden bullet, and that for these ranges it is not so accurate.

Greater penetration was another important advantage claimed by Hebler, and this claim was sustained by experiment. In unseasoned oak, firing across the grain three feet from the muzzle, the old leaden .45 calibre bullet from the Springfield rifle penetrates but five or six inches, while the steel-jacketed bullet of our present service rifle at the same distance will penetrate nineteen or twenty inches.

The last of the advantages claimed by Hebler, and the one of greatest interest to mankind, was that *the wound produced, though sufficient to disable, is much more humane.* This claim could be determined only by experiments on cadavers, and on the lower animals, and by observation of the actual conditions in battle. In all the leading countries of the world, from 1886 to the present time, competent men have been experimenting upon the lower animals and upon dead human bodies, for the purpose of ascertaining the character of the wounds inflicted by the different missiles employed in warfare. The Surgeon-General of the Austrian army, Johann Habart, Chauvel and Ninier, of the French army, Bruns, of Germany, and many others have furnished us important data upon the effects of the new arm. In this country the subject was first undertaken in 1893 when the change in our armament took place.*

Although there was some difference in the mechanism of the guns used by the different experimenters, the projectiles which they propelled differed but little as to calibre and destructive effects. The most of the experiments were conducted at simulated ranges. That is to say, if the work at Frankford Arsenal be taken as an example, all of the firing was done at fifty-three feet. When it was desired to obtain the effects of a bullet at a certain range, the charge of powder was reduced in quantity enough to give the bullet the remaining velocity for that range. The results thus obtained were generally uniform, and, as far as the experimenters were concerned, sufficiently conclusive. Some critics refused to accept the results of the experimenters as final, upon the ground that the simulated velocities of the projectile, and the dead tissues fired into, did not represent the conditions that must obtain in war. It is specially gratifying to those who labored upon the problems involved to find that their deductions have been amply justified by clinical evidences in war, and especially by the revelations of the *x*-ray. When one reflects that it has been the usage of French military surgeons for generations to study gunshot wounds by firing into cadavers, and that it is done by order at Val de Grâce to this day, the practice has this claim to recommend it at least.

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* Annual Report, Surgeon-General United States Army, 1893.

In order to make the results more apparent we adopted the following plan at Frankford Arsenal: We noted (1) the effects of a projectile of larger calibre and lower velocities upon different parts of the human body at various ranges; and (2) the effects of a projectile of the smaller calibre and greater velocities upon similar parts of the human body, or upon parts offering about the same resistance at similar ranges. The larger calibre weapon selected was the Springfield rifle, calibre .45, the gun which had formed the armament of our foot troops since 1873. The smaller calibre weapon employed, and to which the experiments were especially directed, is known as the Experimental Springfield rifle, calibre .30.

The following is a description of the more important ballistic properties of these weapons: "The Springfield rifle is a .45 calibre gun, the projectile of which has an initial velocity of 1,301 foot seconds. Its projectile is made of compressed lead, cylindro-conoidal, cannelured, and lubricated, weighing 500 grains, impressed by 70 grains of black rifle powder. The Experimental Springfield rifle is a .30 calibre gun, the projectile of which has an initial velocity of 2,000 foot seconds. Its projectile is made of a German silver jacket filled with a core of lead, and is not cannelured or lubricated."

It will be seen by Table II. that the initial velocity of the smaller calibre projectile is far greater than that of the larger calibre, and that the striking velocity at all the ranges is greater.

The penetration of a bullet is proportional to the square of its striking velocity; for equal velocities the penetration is proportional to the density of section. The form of the bullet and its power to resist deformation have a powerful influence. The penetration of the 220-grain bullet is greater at all ranges. This quality of penetration in projectiles is always of great interest to surgeons, and it becomes especially so in this instance, since it depends to a material extent, as far as the human body is concerned, upon the almost indestructible hardness of the projectile.

In the experimental work referred to, the penetration at the different ranges was obtained as follows: A Le Boulenge chronograph was used, the distance between first and second targets being 100 feet, and the first target being 3 feet from the muzzle. The remaining velocities of both bullets used (500 grains, .45 calibre, and 220 grains, .30 calibre) were computed for the desired ranges by the methods given in Ingall's "Exterior Ballistics." To find the penetration at a given range, say 1,000 yards, the procedure was as follows: The remaining velocity at this range computed as above, was found to be 676 foot seconds for the 500-grain bullet. The charge of powder was successively reduced until a charge was found which gave at 53 feet from the muzzle a velocity of 676 foot seconds. Cartridges were made up with this charge, and the cadaver to be fired at was placed at 53 feet from the muzzle. The striking velocity of the bullet being the same as that of a bullet fired with the full charge and striking an object at a distance of 1,000 yards the penetration would also be the same. At the ranges of 1,500 and 2,000 yards respectively, it was found necessary, in order to record the low velocities obtained, to reduce the distance between targets to 50 feet, which caused the velocity to be determined at 28 feet from the muzzle. At these ranges, therefore, the cadavers were placed 28 feet from the muzzle. A tackle was provided for traversing the cadavers and bringing a portion of the body to be fired at into proper position. Barrels filled with sawdust were placed behind the cadaver experimented with, to catch the bullets and preserve them from deformation other than that received in their passage through the body. Each bullet was marked on its base with a number or letter, for the purpose of identification, and after firing at each range the bullets were collected and examined.

Before proceeding to the observation of gunshot injuries proper, some facts were noted on impact and explosive effects, as follows:

Impact.—The shock as shown by the oscillation of the limb, when a resistant bone was hit, was always greater with the leaden bullet of .45 calibre than with that of the smaller-bore gun; on the other hand, the difference was reduced to a minimum when the soft parts alone were hit. It often happened that the occurrence of a fracture from the impact of the smaller projectile was determined only after a careful examination of the wound. This difference in shock was noted at all the ranges, but especially so after the 500-yards range.

The minimum amount of shock for the smaller projectile depends upon the superior penetration, which, as stated already, is due to its smaller calibre, greater velocity, and last, but not least, because it preserves its shape unaltered. The fact that the calibre of the Springfield was greater sufficed to explain the greater amount of shock. This was added to by deformation. Part of the energy was consumed in the flattening of the bullet, while the remainder was conveyed to the part hit in the form of shock. The difference in the amount of shock is at once suggested in Table II., already cited. It will be seen that the striking energy in foot pounds for all the ranges is greater with the projectile of the .45 calibre Springfield rifle.

Explosive Effects.—The explosive effects caused by the projectile of the Springfield rifle were noticed up to 200, and in some instances up to 250 yards, while the explosive effects of the projectile of the experimental Springfield rifle extended in some instances as far as the 350-yards range.

The term "explosive effects" is somewhat confusing, as it is apt to convey the idea that the wound was caused by an explosive bullet. It is a term that doubtless owes its origin to the similarity in the appearance of the two wounds. When we say that a wound shows explosive effects, we mean that it appears as though it had been caused by an explosive bullet. As a rule, the wound of entrance presents no special features to which attention should be called. In only a few instances is a certain amount of bone sand found in the tract leading to a fractured bone. When a resistant bone has been hit, the foyer of fracture will show great loss of substance, the bone will have been very finely comminuted, the pulverized bone will have been driven not only in the direction in which the projectile was travelling, but in all directions, and the pulpification of the soft parts will not only be limited to the track of the bullet, but utter destruction is noticed for some distance into the surrounding tissues. The wound of exit appears like a bursting forth of the skin; the track leading to the bone is conical in shape, the base of the cone corresponding to the wound of exit in the skin and the apex to the seat of fracture.

The degree of explosive effects corresponds to the velocity of the projectile at the moment of impact and the resistance offered by the part hit.

The bony structures are not alone in showing explosive effects with high velocities. Explosive effects have been noted with the projectile of the reduced calibre weapons up to 500 metres in "very vascular tissues, cavities filled with liquid or semi-liquid or viscous masses, such as the skull, heart, liver, spleen, kidneys, stomach, intestines, and bladder, which have been attributed by some observers to hydraulic pressure."

In order to test the influence of hydraulic pressure in causing explosive effects, some interesting experiments were conducted at Frankford Arsenal.

1. Empty powder cans were fired into at various ranges. The orifices of entrance and exit were found proportional to the size of the projectiles employed. The cans were not deformed, showing no explosive effects.

2. A half-dozen or more powder cans from the same lot were filled with wet sawdust. The cans were fired into at various ranges. The orifice of entrance in each case presented no special features. The orifice of exit, however, for both projectiles was marked by a bursting forth of the tin and loss of the contents. The cans had been expanded as if by an internal force, which had been exerted in all directions. The explosive effects were about the same for both bullets.

3. Another lot of powder cans of the same size and dimensions was filled with water and fired into. The results were quite similar to those observed in the case of the wet sawdust, only more extensive, and they were about equal for the two projectiles.

The following observations upon the explosive effects of projectiles at relatively short ranges picture in a marked degree the wounds that surgeons have to treat, as a result of high velocities, and unless one is prepared to interpret their true cause he is apt to fall into very erroneous conclusions.

Notes of Gunshot Injuries on the Human Body; Experiments Conducted at Frankford Arsenal, Pennsylvania, on March 18th, 1893, with the Large and Small Calibre Projectiles, for the Purpose of Noting the Explosive Effects at Relatively short Ranges.

1. Gunshot injury, left humerus, at junction of middle and lower thirds; bullet No. 4, calibre .45; range, 17 yards. The wound of entrance is oval, .55 inch in its greatest diameter. The wound of exit is marked by a chasm on the back of the arm four inches in length, 2.36 inches in width, the edges of which are ragged. There is eversion of muscle and fat. The soft parts contain minute fragments of bone, which have been driven some distance into the tissues. The bullet struck the humerus at the junction of the middle and lower thirds. The foyer of fracture shows a loss of substance of the shaft 1.60 inches in length. There is extensive comminution. The fragments (twenty-three being readily counted) are greatly displaced, and the majority of them are free from the periosteum. The bullet is very much mushroomed, having lost about one-half in weight.

2. A gunshot injury by the .30 calibre projectile, at the same range, on the opposite arm produced a wound of entrance which is round, .35 inch in diameter. The wound of exit is 4.30 inches in length, and 2.36 inches in width. It is marked by pulpification of the muscular tissue, which contains bone sand. The missile struck the shaft of the humerus above the middle, comminuting the bone extensively, but not to the extent observed in the preceding injury with the .45 calibre leaden projectile. Fourteen principal fragments were readily counted. They are large and not so much displaced as in the injury on the left humerus. The larger fragments are retained in place by their periosteal attachment. The fissures are not so extensive in the shaft above and below the seat of injury. The projectiles were recovered, the leaden nucleus having escaped from the harder metallic mantle. The cylindrical part of the envelope is intact, the conical end having split in four pieces, one of which is entirely detached from the shell.

3. Gunshot injury of the left tibia, middle third; bullet No. 5, calibre .45; range, 17 yards. The wound of entrance is round, .45 inch in diameter; the wound of exit is marked by a longitudinal tear in the calf 3.16 inches in length and 1.18 inches in width. The bullet struck the shaft of the tibia at the junction of the middle and upper thirds, shattering the bone extensively. The seat of comminution measures 4.30 inches; the fragments, which are all detached, have been displaced backward. Large numbers of fine spicula of bone have been driven into the muscle of the calf. The soft parts are reduced to a pulp-like mass for some distance beyond the walls of the chasm-like opening. The fibula is broken at the same level. The projectile was split into two lateral halves at the conical end, one of which was lost, whilst the other remains attached to the cylindrical portion.

4. A gunshot injury by the .30 calibre projectile at the same range on the opposite tibia shows a wound of entrance which is round, .30 inch in diameter, and a wound of exit which is marked by an oblique tear extending from the lower part of the popliteal space to the lower part of the calf, measuring 6.66 inches in length and 2.36 inches in width.

The bullet collided with the tibia at its inner border 4.30 inches below the knee-joint, comminuting the shaft. Upon removing the skin the wound of entrance is seen to be filled with bone sand, the periosteum over the crest of the shaft is partly torn; on the outer side several large, sharp splinters of bone remain attached to the periosteum; the posterior wall of the shaft below the popliteal space, two inches in extent vertically, has been entirely destroyed and spicula of bone and medulla are seen in the lacerated muscle of the calf. The fibula is fractured in two places just above the level of the fracture in the tibia. The muscle of the calf has been reduced to pulp.

The projectile was very much deformed; but one fragment of the metallic mantle was recovered; it measured .79 inch in length and .39 inch in width. The leaden nucleus was mushroomed and is only half the original length.

It will be seen from the foregoing that the explosive effects at short range differ but little for the two projectiles, and that they are always enormous.

Notes on the Effects, on the Human Body, of the Projectiles of Large and Small Calibre Impressed by the Velocity Common at 350 yards; Experiments Conducted at Frankford Arsenal, Pennsylvania, January 12th, 1893.

1. Gunshot injury of the left ankle; bullet No. 2, calibre .30. The wound of entrance is 1.18 inches below the tip end of the internal malleolus; it is star-shaped, .39 inch in its greatest diameter. The projectile entered the astragalus at the lower margin and at its articulation with the os calcis. A portion of the bone belonging to the astragalus at this point, .59 inch long by .39 inch wide, is lying in the wound, attached by periosteum. The posterior portion of the trochlear surface of the os calcis, .59 inch long by .39 inch wide, is partially detached. The missile passed between the os calcis and the astragalus and emerged through the upper portion of the os calcis next to the outer margin of the articulation. There are several free fragments from the latter bone in the wound of exit. The tip of the external malleolus was crushed by the projectile. The projectile was not deformed.

2. Gunshot injury of the left ankle joint; bullet No. 3, calibre .45. The wound of entrance is round, 3.54 inches in diameter, and torn, the tears radiating from the edges of the wound. The wound of exit is irregularly quadrilateral in shape, .79 inch in its greatest diameter. The bullet entered through the internal malleolus and made a grooved fracture of the astragalus; there is complete pulverization of the inner half of the articular surface of the tibia. The missile then passed out, piercing the posterior portion of the external malleolus, the anterior portion remaining attached to the shaft. The projectile was mushroomed.

3. Gunshot injury of the right foot; bullet No. 4, calibre .30. The wound of entrance is .35 inch in diameter, 1.18 inches in front of the external malleolus. The wound

of exit was found, after several minutes of patient searching, to be located in the sole of the foot, 1.38 inches from the internal malleolus. It is marked by a slit-like opening .28 inch in length. The edges of the slit approximate each other thoroughly, hence the difficulty experienced in locating the wound. The projectile entered the os calcis near its articulation with the cuboid and below the head of the astragalus, fracturing the calcaneo-cuboid articulation, splintering the bone in three fragments, near which a small amount of pulverized bone is found. All the bones of the tarsus are intact except the os calcis. The projectile was recovered unaltered in shape.

4. Gunshot injury of the left tibia and fibula near knee-joint, bullet No. 5, calibre .30. The wound of entrance is round, .39 inch in diameter; the wound of exit is marked by a longitudinal slit, measuring .39 inch in length. The projectile entered the anterior portion of the head of the tibia, .39 inch from the joint, in the middle line, passing obliquely toward the outer side, and emerged from the posterior surface of the head of the fibula. The orifice of entrance in the bone is equivalent to the diameter of the missile; the orifice of exit is irregular, .39 inch in its greatest diameter. There is no comminution of bone. The knee-joint was not perforated, but the articular surface adjacent to the outer tuberosity shows a fissure which in the recent state was not apparent. The projectile was lost.

5. Gunshot injury of the lower shaft of the right femur; bullet No. 3, calibre .45. The wound of entrance is 1.57 inches above the outer condyle, round, and .45 inch in diameter. The wound of exit is in the upper part of the popliteal space, irregularly quadrilateral in shape, .79 inch in its greatest diameter. The bullet entered the lower shaft, 1.57 inches above the margin of the articular surface, .39 inch outside the middle line. Nine large splinters are detached, measuring from .6 inch to 3.50 inches in length. There are a number of deep vertical fissures in the upper and lower fragments; those in the lower do not invade the joint. The projectile was very much set up.

6. Gunshot injury of the right hip joint. Bullet No. 6, calibre .30. The wound of entrance is .35 inch in diameter, over the femoral vessels, 1.57 inches below Poupart's ligament; the wound of exit is in the middle of the gluteal region of the corresponding side, oval in shape, and exceeds very little the diameter of the projectile. The bullet entered the capsular ligament at its inner margin and traversed the head of the femur, .79 inch below the ligamentum teres, producing a grooved fracture. The course of the projectile was horizontal and clear-cut; a fracture, 1.57 inches in length, is noticed extending downward through the ischium. The compact bone adjacent to the track of the bullet shows fissures not apparent in the fresh state. The missile entered the acetabulum, 1.97 inches from the lower margin in the cotyloid notch. The orifice of entrance corresponds nearly to the diameter of the projectile; the orifice of exit is irregular, 1.97 inches in its two diameters. A fragment of the outer plate of bone, .39 inch in length, hangs attached by periosteum. The projectile was not in the least deformed.

7. Gunshot injury of the left hip joint; bullet No. 7, calibre .30. The wound of entrance perforated the skin on the anterior aspect of the thigh, external to the large vessels, 1.57 inches below Poupart's ligament. The wound of entrance is round, .30 inch in diameter; the wound of exit is also round, in the middle of the gluteal region, and it barely exceeds the diameter of the missile. The projectile entered the anterior convexity of the head of the femur, after passing through the capsular ligament; the acetabulum was not involved until after the bullet had passed through the head of the femur. The projectile traversed the head of the femur in a horizontal direction, .30 inch above a horizontal line drawn through the centre of the head, and emerged at its posterior surface 1.28 inches external to the ligamentum teres. A fissure is seen connecting the points of entrance and exit, and extending outward along the upper margin of the attachment of the capsular ligament; there are smaller fissures that radiate from the orifice of entrance. No splinters are detached. The outer lip of the acetabulum, however, was split, and is held in place only by the capsular ligament. The bullet at the orifice of exit penetrated the acetabulum, .59 inch from the outer margin, emerging without detaching any splinters, excepting as noted, and left clean-cut orifices upon entering and leaving the bone. The orifices of entrance and exit in the globular head of the femur are round and equal to the diameter of the projectile. The orifice of entrance in the pelvis is round, and exceeds by only a fractional part the diameter of the projectile; the orifice of exit is .59 by .39 inch in diameter, with the margins of the orifice slightly elevated. The bullet was not deformed.

8. Gunshot injury of the right elbow joint; bullet marked "E," calibre .30. The wound of entrance is on the external aspect of the arm opposite the bend of the elbow, 2.36 inches from the olecranon; it is round, and equal in diameter to that of the projectile; the wound of exit is .59 inch below the tip of the olecranon; it is star-shaped, and .30 inch in its greatest diameter. The projectile passed through the head of the radius, permitting the outer and posterior aspect of the forearm to receive the wound; the head is split in two portions, one half of which is finely comminuted, while the outer half, together with its portion of the neck and .79 inch of the shaft, remains in place without much damage to the periosteum. The pulverized bone, comprising the inner half of the head, lies free in the joint. The projectile entered the ulna .20 inch below the joint, near the posterior margin of the lesser sigmoid cavity; the olecranon is completely crushed; fissures extend through the greater sigmoid cavity, and the posterior portion of the articular surface. There are seventeen small splinters detached from the periosteum about the foyer of destruction. The projectile was slightly dented on one side in the cylindrical portion; otherwise it sustained no deformation.

9. Gunshot injury of the right shoulder joint; bullet No. 6, calibre .30. The wound of entrance is round, .30 inch in diameter; it perforated the skin well up on the anterior aspect of the shoulder, .39 inch below the acromion; the wound of exit is irregular in shape, .59 inch in its greatest diameter, on the posterior aspect of the shoulder, 4.72 inches from the wound of entrance, measuring over the shoulder. The projectile entered the bone in the bicipital groove between the two tuberosities and traversed the head of the humerus, crushing the head in passing out posteriorly. One large splinter, 1.18 inches by .98 inch, was carried through the orifice of exit in the bone and found embedded in the infraspinatus and teres minor muscles. Four other splinters comprising the globular head of the humerus lay about the seat of fracture; the central portion of the head is pulverized and discolored by lead. The bullet was not recovered.

NOTES ON THE DESTRUCTIVE EFFECTS ON THE HUMAN BODY, OF THE PROJECTILES OF LARGE AND SMALL CALIBRE IMPRESSED BY THE VELOCITY COMMON AT 1,200 YARDS. EXPERIMENTS CONDUCTED AT FRANKFORD ARSENAL, PENNSYLVANIA, MARCH 9TH, 1893.

1. Gunshot injury of the lower third of the left femur; bullet marked "J," calibre .45. The wound of entrance is round, .45 inch in diameter; the wound of exit is in the upper part of the popliteal space, marked by a slit running obliquely, 1.38 inches in length. The missile struck the shaft of the left femur 2.36 inches above the articular cartilage on the inner side of the median line. The bone immediately behind the point of impact, covering an irregular space 1.5 by 2 inches in diameter, was carried away and lies finely comminuted in the track of the bullet; only a fraction of the number of the splinters of bone could be recovered. Some fragments of lead were found with the bone sand. The projectile was very slightly flattened in the cylindrical portion near the base; one-third of the conical portion of the bullet was severed

laterally and lost; the remaining two-thirds are flattened laterally.

2. Gunshot injury of the head of the right tibia; bullet marked "K," calibre .30. The wound of entrance is .30 inch in diameter, and .59 inch below the patella; the wound of exit is in the upper part of the calf; it is quadrilateral in shape, .30 inch in its largest diameter. The projectile perforated the head of the tibia in the middle line, .39 inch below the articular surface. The diameter of the track of the projectile corresponds to the diameter of the missile; the orifice of exit is on the posterior surface, .39 inch distant from the articular facet for the fibula. No large fragments were found in the tissues. The fibula and the articular surface of the head of the tibia are uninjured. The projectile was not deformed.

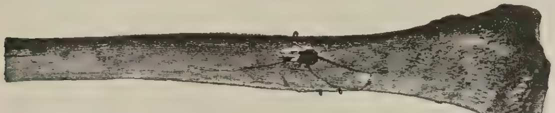

FIG. 2357.—Gunshot Injury of the Right Tibia, at the Junction of the Upper and Middle Thirds, by the ."30 Calibre German-Silver Jacketed Projectile with the Velocity Common at 1,200 Yards. The projectile penetrated the shaft six inches below the knee joint. Examination immediately after the shot was fired revealed no mobility, although upon dissection a distinct fracture was observed. The displacement of the principal fragments is very slight.

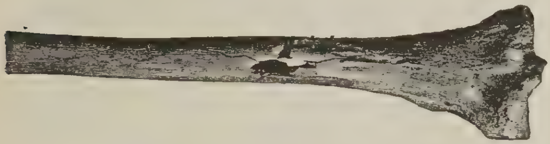

FIG. 2358.—A Posterior View of Fig. 2357.

3. Gunshot injury of the lower end of the right femur; bullet marked "D," calibre .30. The wound of entrance is round, .30 inch in diameter, .79 inch above patella; the wound of exit is in the internal and upper part of the popliteal space, marked by a quadrilateral orifice having a punched-out appearance, .79 inch in its greatest diameter. The projectile perforated the anterior face of the bone about its middle, immediately above the upper margin of the articular surface. A small quantity of finely pulverized bone was found in the wound of exit. There was no fissuring, and the articular surface was uninjured. The projectile sustained a slight flattening of its tip at the conical end.

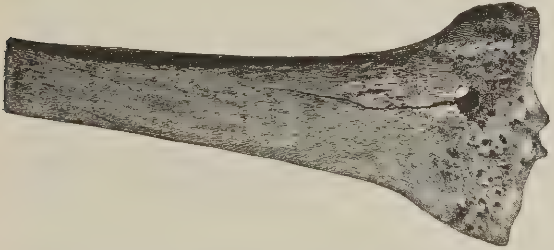

FIG. 2359.—Gunshot Injury of the Head of the Right Tibia by the ."30 Calibre German-Silver Jacketed Projectile with the Velocity Common at 1,200 Yards. The projectile perforated the head of the tibia in the middle line ."39 below the articular surface. The diameter of the track of the bullet in the bone corresponds to the diameter of the missile.

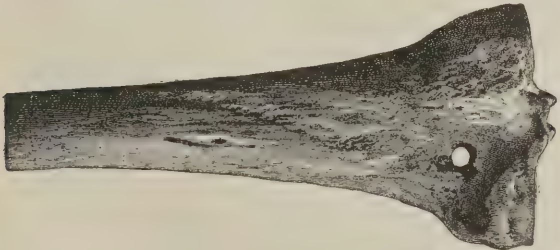

FIG. 2360.—A Posterior View of Fig. 2359.

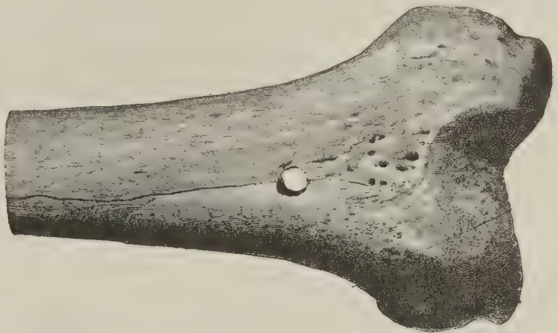

FIG. 2361.—Gunshot Injury of the Lower Third, Right Femur, by the ."30 Calibre German-Silver Jacketed Projectile with the Velocity Common at 1,200 Yards. The projectile perforated the anterior face of the bone about its middle, immediately above the upper margin of the articular surface, making a clean-cut perforation. The fissure occurred in drying; it was not present in the recent state.

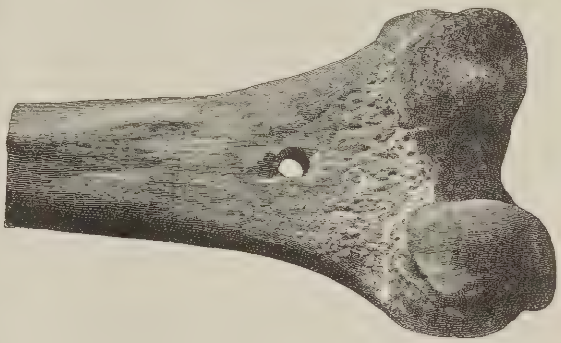

FIG. 2362.—A Posterior View of Fig. 2361.

4. Gunshot injury of the left knee-joint; bullet marked "B," calibre .45. The wound of entrance is round, .45 inch in diameter, a little internal to the middle of the patella; the bullet ranged downward, backward, and outward, inflicting, in the fleshy part of the

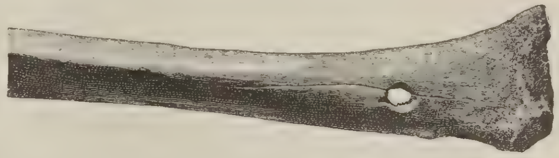

FIG. 2363.—Gunshot Injury, Right Tibia, near the Ankle, by the ."30 Calibre German-Silver Jacketed Projectile with the Velocity Common at 1,200 Yards. The bullet perforated the tibia on the anterior aspect in the middle line 2."17 above the ankle joint. The orifice of entrance has a punched-out appearance equal in diameter to that of the projectile. The fissure occurred in drying; it was not present in the recent state.

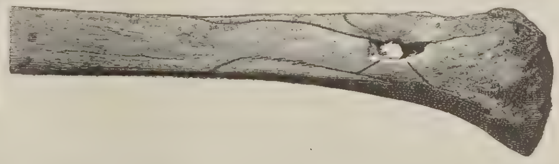

FIG. 2364.—A Posterior View of Fig. 2363. Fissures are exaggerated by drying.

calf, a wound of exit which is quadrilateral in shape, .79 inch in length. The bullet entered the patella on the inner side of the median line and passed through the outer condyle, emerging .79 inch from the point of entrance, splitting the outer tuberosity. A slight outward displacement of the fragments shows a fissure extending upward to the margin of the articular cartilage. The patella is broken into a number of fragments. Passing downward the bullet entered the left tibia, carrying away a portion of the outer cartilage and grazing the top of the fibula. The bullet was flattened laterally along its cylindrical and conical portions on one side, and flattened at the conical end alone on the opposite side.

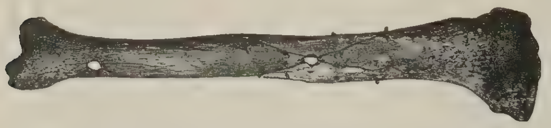

FIG. 2365.—The Specimen Shows Two Perforations of the Right Tibia by the ."30 Calibre German-Silver Jacketed Projectile with the Velocity Usually Possessed at 1,200 Yards. The perforation in the middle of the shaft shows two fissures crossing each other in the form of an "×." There is a complete fracture. The lower perforation is attended with less fissuring. There is no solution of continuity.

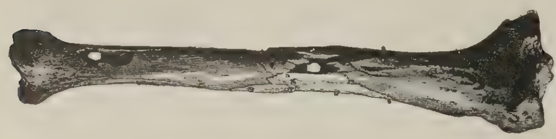

FIG. 2366.—A Posterior View of Fig. 2365.

5. Gunshot injury of the left tibia and fibula near the ankle joint; bullet marked "G," calibre .45. The wound of entrance is over the ankle in front, round, .45 inch in diameter. The wound of exit is just above the external malleolus between the tendo Achillis and the fibula. It is marked by a longitudinal slit, 1.38 inches in length. The bullet entered the tibia 1.18 inches above the ankle joint in the median line; the missile struck the tendon of the tibialis anticus muscle, displacing it to the outer side. The inner portion of the shaft and internal malleolus remain intact. The shaft of the outer side is fissured irregularly; a zigzag line extends between the points of entrance and exit. The fibula is fractured at the same level. The bullet is flattened in the cylindrical portion near the base, and flattened laterally at the conical end, the flattened surface at the latter point being very irregular.

6. Gunshot injury of the right tibia near the ankle; bullet marked "H," calibre .30. The wound of entrance is over the lower part of the leg anteriorly, round, .30 inch in diameter. The wound of exit lies in the same place posteriorly; it presents a punched-out appearance, is triangular in shape, .30 inch in its greatest diameter.

The bullet perforated the tibia on the anterior aspect in the median line, 2.17 inches above the ankle joint. The orifice of entrance has a punched-out appearance; it is .30 inch in the vertical and .24 inch in the horizontal direction. There is a fissure 3.75 inches long, extending upward from the perforation; it is seen through the periosteum, the latter being intact. Posteriorly between the foyer and the wound of exit in the skin many fine splinters of bone are distributed, the fibula is uninjured. The bullet is very little flattened at the conical end.

7. Gunshot injury of the right knee; bullet No. 1, calibre .45. The wound of entrance is .30 inch internal to and above the patella; it is round, .45 inch in diameter; the wound of exit is in the middle of the popliteal space, star-shaped, .59 inch in its greatest diameter. The bullet entered the bone 1.18 inches above the articular surface. The diameter of the perforation corresponds to the diameter of the missile. The orifice of exit posteriorly admits the index finger and is situated in the popliteal space above the trochlear surface of the inner side of the median line. The bullet was recovered, very little dented at the conical end.

8. Gunshot injury of the upper third of the left femur; bullet No. 2, calibre .45. The wound of entrance is round, .45 inch in diameter; the wound of exit is marked by a slit-like opening running longitudinally, 1.18 inches in extent. The projectile entered the anterior aspect of the femur and shattered the bone above its middle. Nine large splinters, from 4 inches to .40 inch in length, are found in the foyer of fracture, and only partially held by the periosteum. The bullet was set up and dented at one side at the conical end.

9. Gunshot injury of the upper third of the right femur; bullet No. 1, calibre .30. The wound of entrance is round, .30 inch in diameter; the wound of exit is in the fleshy portion of the thigh, quadrilateral in shape, .79 inch in its greatest diameter. The bullet entered the bone 5.50 inches below the trochanter major, comminuting the shaft. The largest fragment is 4 by 1.18 inches, and is firmly adherent to the surrounding tissues. The specimen shows an old united fracture of the upper shaft passing obliquely and immediately below the trochanters. The bullet was flattened at the conical end and distorted to one side; the leaden nucleus protrudes from the mantle at the base.

10. Gunshot injury, right tibia, middle of shaft; bullet marked "T," calibre .30. The wound of entrance is round, .30 inch in diameter; the wound of exit is marked by a slit in the calf, .35 inch in its greatest length. The bullet struck the subcutaneous surface of the tibia at its middle, splintering the bone into several large fragments; the largest one, embracing the crest of the tibia, is 5 inches long. Viewed from the inner side the fissures cross at the point of impact, so as to form an "X." The periosteum is intact and binds the fragments together so that, as the dissection would indicate, there is no reason to suppose that the fracture would not unite readily. A large number of fine splinters of bone were found in the muscular tract of the calf, near the seat of fracture. No great laceration of soft parts was observed. The fibula was not injured. The projectile was dented at the conical end.

11. Gunshot injury, right tibia near the ankle joint; bullet marked "C," calibre .30. The wound of entrance is round, .30 inch in diameter; the wound of exit is marked by a slit .30 inch in length. The bullet perforated the shaft 2 inches above the internal malleolus. On removing the skin the orifice of entrance in the bone presents sharply cut edges, and it corresponds in size to the diameter of the missile. The bullet passed out at the posterior aspect of the bone, the orifice at this point being irregular in shape and a trifle larger than the ori-

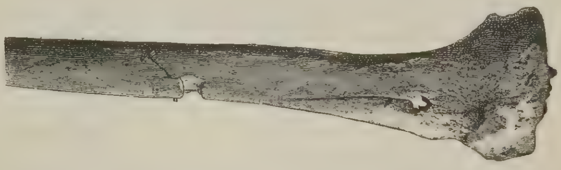

FIG. 2367.—This Specimen Shows a Complete Perforation in the Upper Part of the Shaft of the Left Tibia by the ."30 Calibre German-Silver Jacketed Projectile with the Velocity Common at 1,200 Yards. There is also an injury in the middle of the shaft by a ."30 calibre projectile at the same range. The bullet struck the crest of the tibia, passing wholly in front of the medullary canal, and producing a gutter in the crest. There is a complete fracture. There is no record of the injury near the ankle.

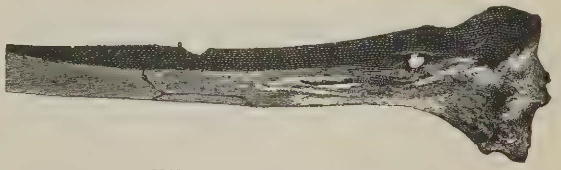

FIG. 2368.—A Posterior View of Fig. 2367.

fice of entrance. A few splinters of bone were found in the track of the bullet leading from the bone. The projectile was not deformed.

Notes on the Effects, on the Human Body, of the Projectiles of Large and Small Calibre Impressed by the Velocity Common at 2,000 Yards. Experiments conducted at Frankford Arsenal, Pennsylvania, March 16th, 1893.

1. Gunshot injury left tibia, middle third; bullet No. 1, calibre .45. The wound of entrance is oval in shape, .51 inch in its greatest diameter. The projectile remained lodged under the skin of the calf. The bullet entered the subcutaneous part of the shaft, 5.50 inches below the knee joint, causing extensive comminution of the bone at the foyer of fracture, including 2 inches of the shaft. Some of the fragments are free whilst others remain attached to the periosteum. The bullet was found under the skin of the calf; it was cleft longitudinally through the conical part, one-half of the cone having become detached from the cylindrical part. The detached fragment was found embedded in the tibialis anticus muscle.

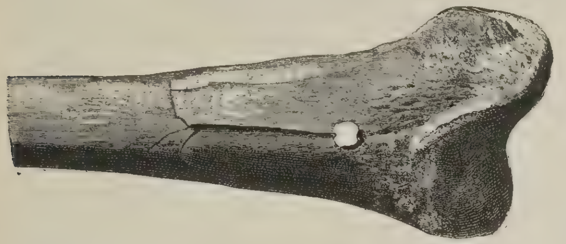

FIG. 2369.—Gunshot Injury, Lower Third, Right Femur, by the ."30 Calibre German-Silver Jacketed Projectile Propelled with the Velocity Usual at 2,000 Yards. The projectile entered the bone ."79 above the articular surface, making a perforation with long fissures.

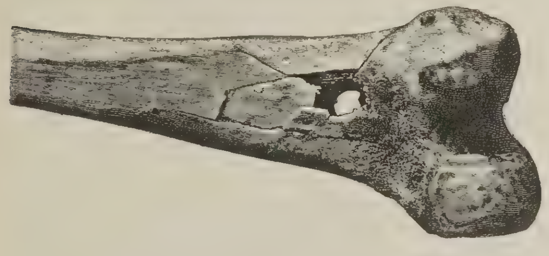

FIG. 2370.—A Posterior View of Fig. 2369.

2. Gunshot injury of the right tibia at junction of middle and lower thirds; bullet No. 4, calibre .30. The projectile entered side on, inflicting a wound of entrance which runs obliquely, .98 inch long and .39 inch wide. The bullet lies under the skin posteriorly in the lower part of the calf. The bullet guttered the inner side of the tibia 5.12 inches above the internal malleolus. On removing the skin several spicula of bone are seen in the wound; the outer border and crest of the tibia are uninjured; the posterior surface of the bone is splintered over a distance of 3.15 inches in lines which radiate from the point of emergence. The periosteum is not detached, excepting in the line of the passage of the projectile and over an area adjacent to the posterior margin of the groove, between .20 and .40 inch in diameter. The fibula was not injured. The bullet was embedded in the muscle of the calf with its point resting against the skin and its base presenting in the track through the muscle adjacent to the bone, a distance of .79 inch. The projectile is slightly flattened at the conical end, otherwise it is unaltered.

3. Gunshot injury of the left knee joint; bullet No. 2, calibre .45. The wound of entrance is round, .45 inch in diameter, above and internal to the patella; the wound of exit is in the lower part of the popliteal space, oval, and .59 inch in its greatest diameter. The bullet perforated the tibia 1.18 inches below the articular surface. The orifice of entrance in the bone is sharply defined, irregular in shape, .59 inch in the vertical and .39 inch in the horizontal line; the orifice of exit is also irregular, .59 inch in its greatest diameter. There is a fracture of the shaft marked by a fissure, which runs downward and backward; the compact tissue of the upper and posterior surface of the bone is broken by radiating fissures into six fragments. The muscular track from the bone to the wound of exit contains some fine spicula of bone. The projectile was not recovered.

4. Gunshot injury of the right knee joint; bullet No. 9, calibre .30. The wound of entrance is round, .30 inch in diameter and .39 inch from the internal border of the patella at its middle; the wound of exit is in the upper part of the popliteal space marked by an oblique slit-like opening .39 inch in length. The projectile entered the bone .79 inch above the articular surface, making a perforation of the femur; the missile passed out in the median line in the popliteal space, perforating the popliteal vein, but leaving the artery uninjured. The wound is full of venous blood clots. Very fine spicula of bone were found in the track of the projectile leading to the wound of exit. There is a fissure 4.72 inches in length, which extends from the orifice of entrance in the direction of the shaft, and a number of smaller radiating fissures are observed to start from the orifice of exit. The projectile was recovered from the sawdust very much deformed. The metallic jacket was ruptured at the conical end, having a slit running along the side of the cylindrical portion at the end of which a transverse slit occurs, which includes one-half of the cylindrical part of the envelope; the leaden nucleus has parted entirely from the jacket; it is flattened at the conical end, bent upon itself in the cylindrical portion, and scooped out on one side.

5. Gunshot injury of the left femur, upper third; bullet No. 3, calibre .45. The wound of entrance is round, .45 inch in diameter; the wound of exit is on the outer and posterior aspect of the thigh, marked by a longitudinal slit, .59 inch in length. The projectile made a glancing shot, striking the outer aspect of the shaft of the femur 4.72 inches below the trochanter major, and producing an oblique fracture of the shaft from above downward and inward; the fragments are considerably displaced, the lower shaft lying to the outer side; the periosteum is detached about the point of impact, but the fragments of bone are not loosened to any very great extent; there is a fissure extending from the trochanter minor downward a distance of 6 inches. Particles of lead were found in the foyer of fracture. The bullet

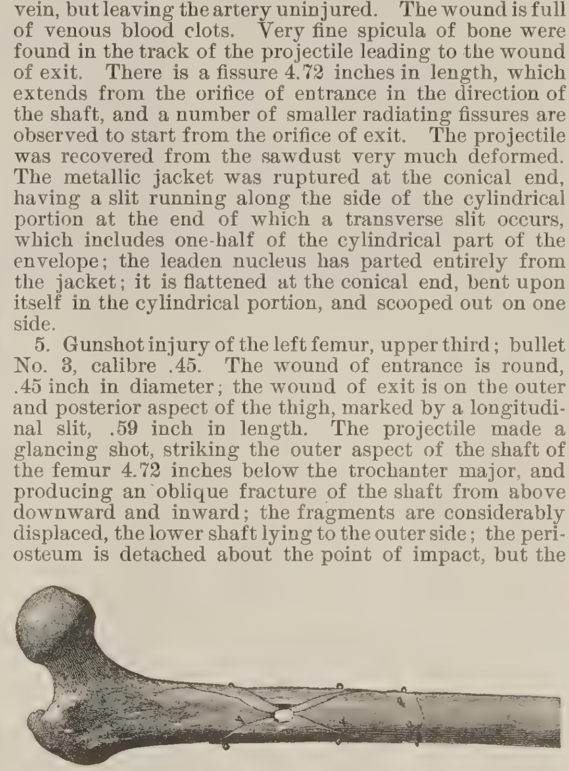

FIG. 2371.—Gunshot Injury of the Right Femur at Junction of Middle and Upper Thirds by the ."30 Calibre German-Silver Jacketed Projectile with the Velocity Common at 2,000 Yards. There is a well-marked perforation with extensive fissuring.

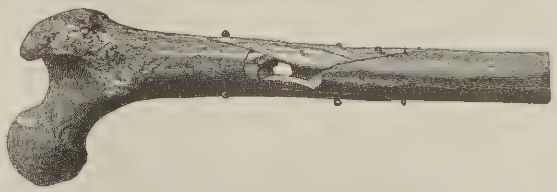

FIG. 2372.—A Posterior View of Fig. 2371.

was seemingly split in two lateral halves nearly equal in weight; the greater half only was recovered.

6. Gunshot injury of the right femur, upper third; bullet No. 0, calibre .30. The wound of entrance is round, .30 inch in diameter; the wound of exit is triangular in shape, .39 inch in its greatest length. The bullet struck the shaft of the femur in the middle line anteriorly, 7 inches below the anterior superior spine of the ilium, comminuting the bone into a number of fragments, which are held by periosteum. The bullet was flattened at the conical end; otherwise it is unaltered.

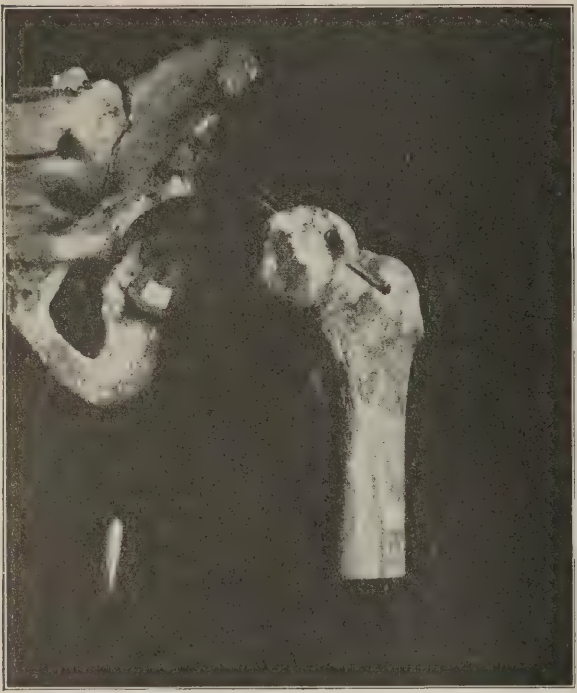
FIG. 2373.—Gunshot Perforation of the Head of Left Femur and Acetabulum by the ."30 Calibre German-silver Jacketed Projectile with Velocity Common at 1,200 Yards. The bullet appears in illustration undeformed.

OBSERVATIONS UPON THE FOREGOING RESULTS.—*Soft Parts.*—The wound of entrance corresponds in diameter as a rule to the diameter of the projectile. In the middle and remote ranges the entrance wound measured less at times than the diameter of the projectile, but the difference was only apparent since the wound invariably admitted a projectile of like calibre to the one having inflicted it. In the short ranges it was often noted that skin overlying bone and resistant aponeurosis was apt to show a wound of entrance actually exceeding in diameter that of the missile. The edges of the wound of entrance were at times clear-cut, but more often they were rolled in, and often blackened for a distance of a line about the circumference. The latter circumstance gave rise to the notion formerly that the discoloration was due to burning, but from experiments to be cited later this fallacy has been forever set at rest.

The wound of exit of the .30 calibre rifle was generally larger than the wound of entrance, and beyond the zone of explosive effects especially, it was generally round, marked at times by a mere slit; again it was star-shaped, T-shaped, semicircular, etc.; the edges were generally turned out. When a wound of exit exceeded in diameter that of the projectile to any extent the circumstance was generally regarded as indicative of bone lesion.

Effects upon the Shafts of Long Bones.—Up to 350 yards the destructive effects of the two projectiles are alike severe. Unless guided by the wound of entrance or other circumstances it is difficult within this range to determine, by the appearance of the injury alone, which of the projectiles has caused the injury. After this range the destructive effects of the smaller projectile become less than those of the larger missile. The fissuring is less, the spicula of bone are larger, and they are more apt to be attached to the periosteum. These differences are especially noticeable from the 500- to the 1,500-yard ranges. At 2,000 yards the smaller bullet again shows rather extensive comminution. This fact has been noted by all observers, and it has been variously explained, though not in a very satisfactory manner. It has been said that the projectile has lost so much of its velocity of translation, when it reaches this part of its course, that it is apt to lodge, and that the velocity of rotation causes such a disturbance, when it is about to engage, that comminution is the result. The angle of impact which is rarely vertical at this range, has been brought forward as a possible cause. Certain it is that a number of the projectiles were observed by us at this range to impinge side on at the moment of impact.

Effects upon Joints.—Before engaging upon this part of the subject it may be stated that the humane wound of the small-bore gun is especially observed in the joints and soft parts. Owing to the reduction in calibre the wounds in the latter partake more of the nature of subcutaneous wounds, and experience shows that they heal very kindly under appropriate treatment.

It is not necessary in this instance to dwell especially upon the destructive effects of the larger leaden projectile upon joints. Suffice it to say that the greater frontage, which it naturally possesses, is made greater still by deformation, and that these facts, in combination with a velocity sufficient to penetrate a joint, serve to convert the .45-calibre projectile into a very destructive missile.

The experiments conducted at Frankford Arsenal show in a striking manner the difference between the two bullets in their destructive effects upon the spongy ends of bones. In order to appreciate this difference it is necessary to go beyond the zone of explosive effects for the .30 calibre projectile, namely 350 yards; even within the latter range perforation with slight fissuring will at times be noticed. From the latter range to the 1,500-yard range perforations and gutterings with little or no fissuring are almost invariably seen. Between 1,500 and 2,000 yards the specimens show perforations still, but there is a tendency to fissuring again, as noted in the shorter ranges (see Figs. 2363 and 2364).

Deformation of Projectiles.—The different kinds of deformation of projectiles represent nearly every form of alteration known. Those of the leaden projectiles are sufficiently familiar and require no comment. The deformation of the jacketed projectile is most common at the conical end which consists usually in a slight dent or flattening, and partial separations of the metallic mantle

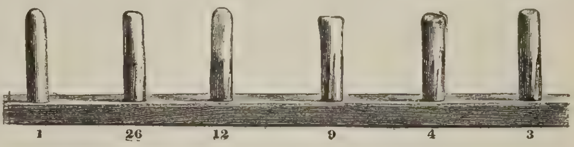

FIG. 2374.—Specimens Showing the More Common Deformations of the ."30 Calibre German-silver Jacketed Projectile. No. 1, A normal ."30 calibre German-silver jacketed projectile which was never fired. No. 26, A ."30 calibre German-silver jacketed projectile showing the deformation sustained upon fracturing the middle of the shaft of the tibia, when propelled with the velocity usual at 1,200 yards. No. 12, A ."30 calibre German-silver jacketed projectile showing the deformation sustained upon causing a fracture with slight comminution of the lower half of the humerus, while propelled with the velocity common at 1,500 yards. No. 9, A ."30 calibre German-silver jacketed projectile showing deformation after fracture of the middle half of the femur, when propelled with the velocity common at 1,500 yards. No. 4, A ."30 calibre German-silver jacketed projectile showing the deformation upon colliding with the upper third of the femur while propelled with the velocity common at 2,000 yards. No. 3, A ."30 calibre German-silver projectile showing the deformation sustained upon fracturing the middle third of the tibia when propelled by the velocity usual at 2,000 yards.

from the leaden nucleus are occasionally seen; complete separation between the jacket and nucleus is a very rare occurrence. It occurs principally with high velocities at close range, when the projectile encounters resistant bone. Separation of the envelope and nucleus was noticed very seldom in the middle and remote ranges.

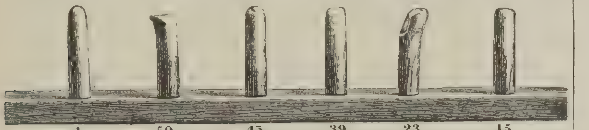

FIG. 2375.—Specimens Showing the More Common Deformations of the ."30 Calibre German-silver Jacketed Projectile. No. 4, This is a normal ."30 calibre German-silver jacketed projectile which was never fired. No. 50, A ."30 calibre German-silver jacketed projectile after inflicting a comminuted fracture of the tibia and fibula with the velocity common at 150 yards. No. 45, A ."30 calibre German-silver jacketed projectile which caused perforation of the astragalus with the velocity usual at 350 yards. No. 39, A ."30 calibre German-silver mantle projectile which inflicted a perforation of the surgical neck of the humerus with little comminution with the velocity common at 350 yards. No. 23, A ."30 calibre German-silver jacketed projectile after inflicting a perforation with slight fissuring of the middle of the shaft of the tibia, when propelled with the velocity usual at 1,200 yards. No. 15, A ."30 calibre German-silver jacketed projectile after inflicting a complete fracture with extensive fissures of the middle of the shaft of the femur, while propelled with the velocity usual at 1,500 yards.

Before we leave the subject of the work done by experiments as to the character of gunshot wounds, for the more practical one in the clinical field, it may be well to admit that the deductions of the experimenters have been questioned by a number of surgeons. On the other hand, the experimenters themselves, the great majority of whom have largely dealt with gunshot injuries as actually observed in accidents and in war, are satisfied to believe that the experimental wounds tally in the main with those which we meet in the actual conditions, and that their judgment has been amply confirmed by the accumulated experience in the Spanish-American and South-African wars.

The Heat Imparted to Projectiles.—The heat imparted to projectiles by the ignition of the powder, the resistance in the barrel, etc., has been very much exaggerated. Some have gone so far as to claim that the small jacketed bullets are rendered aseptic thereby. In a series of experiments conducted at the Pathological Laboratory of the Johns Hopkins University and Hospital, and also at Frankford Arsenal some years since, we were able to show that this claim is false. In order to arrive at some definite conclusion in the matter a series* of experiments were undertaken for the purpose of obtaining answers to the two following questions:

(1) Are projectiles from portable hand weapons sterilized by the act of firing?

(2) Can a septic bullet infect a gunshot wound?

As a preliminary to the work of noting the effects of firing bullets that had been previously contaminated it was considered proper to ascertain the condition, bacteriologically speaking, of bullets in their original packages. After a number of observations it was found that fifty-three per cent. of all cartridges in their original packages were absolutely free from germs. This is to be ascribed to the cleanly methods which are necessary in their manufacture.

The literature of gunshot wounds shows that the majority of surgeons of the past and present times believe that the act of firing destroys any infection that might have been accidentally or otherwise placed upon the projectile.

In order to ascertain the facts in the matter we fired projectiles, after they had been sterilized by heat, from revolvers that had been similarly sterilized. The projectiles were recovered from sterilized cotton and dropped into gelatin tubes. The latter revealed no growth.

Projectiles covered with dust were then fired from sterilized revolvers into sterilized cotton. As each projectile was recovered it was dropped into a gelatin tube. Colonies appeared in every instance.

In a series of experiments with the .22 and .38 calibre revolvers, the .45 calibre Springfield rifle, as well as the .30 calibre Experimental Springfield rifle, whose ballistic qualities correspond to the Krag-Jörgensen, Männlicher, improved Mauser, Lebel, etc., the projectiles were in all instances infected with the germs of anthrax and fired into sterilized materials and into animals. The tables of results show that anthrax bacilli or spores are seldom, if ever, destroyed by the act of firing.

Bullets infected with the streptococcus of erysipelas, with some of the same culture of tetanus mentioned below, and with the bacillus pyogenes soli of Bolton, were fired through the ears of rabbits with a .45 calibre Colt's revolver. The erysipelas coccus was communicated to one animal, and the bacillus pyogenes soli was recovered from the wound of another; tetanus was not communicated.

A bullet infected with a culture of the bacilli of tetanus was fired into a horse with the modified Springfield rifle with negative results; rabbits inoculated with some of the same culture died promptly. At the suggestion of Prof. Meade Bolton, of the Johns Hopkins Hospital, a bag of tetanus earth was placed against the hip of another horse and the projectile of the .30 calibre Experimental Springfield rifle was fired through the earth into the fleshy part of the ham without result.

Later, a series of experiments were conducted to show the effects of firing infected bullets into animals at 300 and 500 yards.*

Whether bacteria might remain on a projectile in transit through the air for such a number of yards had often been questioned, but the evidence at a distance was identical with that obtained at the proximal ranges.

The foregoing results have justified the following conclusions:

(1) The majority of cartridges in original packages are sterile and free from septic germs.

(2) The sterile condition of cartridges is due to the thorough disinfection and absolute cleanliness observed in the process of manufacture.

(3) The majority of gunshot wounds are aseptic because the vast majority of the projectiles inflicting them are either sterile or free from septic germs.

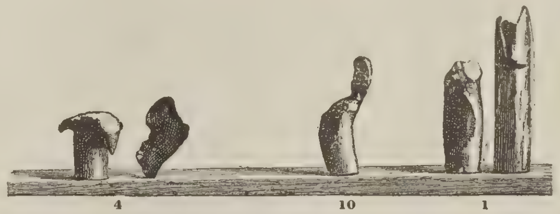

FIG. 2376.—Specimens Showing Unusual Deformations of the ."30 Calibre German-silver Jacketed Projectiles. No. 4, A ."30 calibre German-silver projectile showing separation of the nucleus from the envelope; the nucleus is badly mushroomed, and only a fragment of the envelope was recovered. The projectile was fired into the arm at 17 yards with the full charge of powder. The humerus was pulverized 3 inches in extent, and the soft parts showed extensive explosive effects. No. 10, A ."30 calibre German-silver jacketed projectile showing deformation after causing extensive comminution of the femur, when propelled with the velocity common at 500 yards. The nucleus alone was recovered. No. 1, A ."30 calibre German-silver jacketed projectile showing the deformation sustained after perforating the lower shaft of the femur, when propelled with the velocity usual at 2,000 yards. The nucleus has escaped from the envelope through a rent in the conical end. The concavity in the nucleus was probably sustained by colliding with another projectile in the sawdust.

(4) Anthrax spores or bacilli when applied to the projectile of a portable hand weapon are seldom if ever entirely destroyed by the act of firing.

(5) When a gunshot wound is inflicted upon a sus-

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* N. Y. Med. Journal, vol. lvi., No. 17, p. 458, October 22d, 1892.

* New York Med. Journal, vol. lvi., No. 17.

ceptible animal by a projectile infected with anthrax bacilli the animal becomes infected with anthrax and dies in the vast majority of instances from said infection.

(6) The streptococcus of erysipelas and the bacillus pyogenes soli, when placed upon the projectile of the .45 calibre Colt's revolver, are certainly not always destroyed by the act of firing, and they are liable to cause infection.

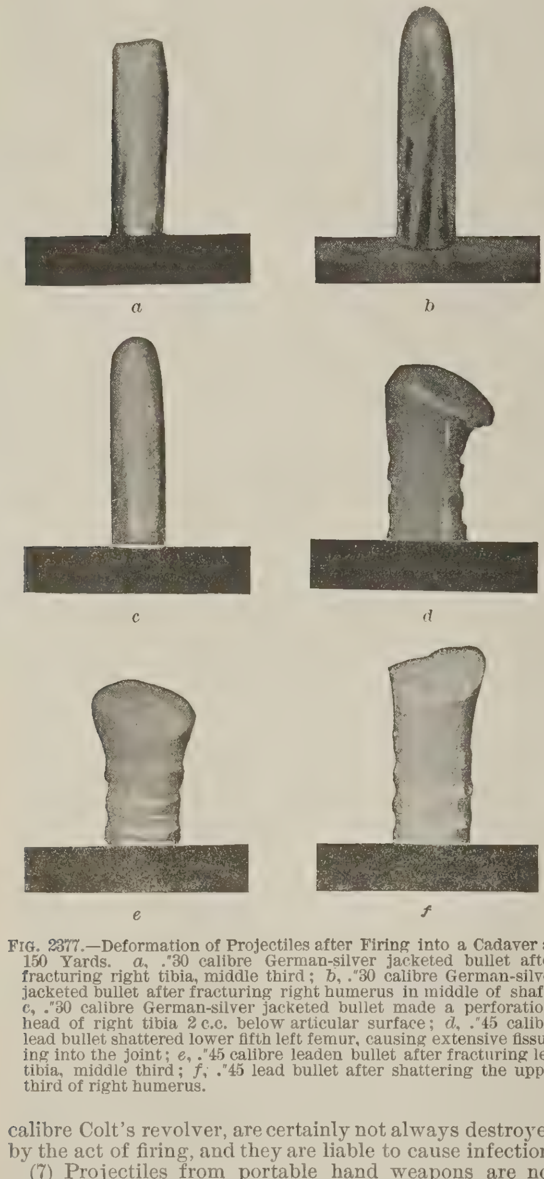

FIG. 2377.—Deformation of Projectiles after Firing into a Cadaver at 150 Yards. *a*, ."30 calibre German-silver jacketed bullet after fracturing right tibia, middle third; *b*, ."30 calibre German-silver jacketed bullet after fracturing right humerus in middle of shaft; c, ."30 calibre German-silver jacketed bullet made a perforation, head of right tibia 2 c.c. below articular surface; *d*, ."45 calibre lead bullet shattered lower fifth left femur, causing extensive fissuring into the joint; *e*, ."45 calibre leaden bullet after fracturing left tibia, middle third; *f*, ."45 lead bullet after shattering the upper third of right humerus.

(7) Projectiles from portable hand weapons are not sterilized by the act of firing.

(8) A septic bullet can infect a gunshot wound.

PRIMARY SYMPTOMS OF GUNSHOT WOUNDS.—The symptoms usually noted in gunshot wounds are (1) pain, (2) shock; (3) primary hemorrhage; (4) thirst; (5) lodgment of the bullet; (6) powder burn, and (7) multiplicity of wounds or, more properly speaking, complications of a primary nature.

(1) *Pain.*—The amount of pain, as an early symptom of gunshot wound, is variable. Indeed it may be said that save in some cases of nerve injury it is not a symptom that reflects the extent or gravity of the injury sustained. The remembrance of the amount and character of the pain at this time of injury is usually vague. Some liken it to a smart tap from a cane, others to a thrill across the tissues, or to a slight sting. During moments of great excitement, in the case of soldiers in battle or of antagonists in duels, the absence of pain is not uncommon. In a certain percentage of cases there is the very opposite of pain, namely a local anæsthesia; the parts about the area of injury have lost their sensibility, the surface is numb to the sense of touch, or to efforts at primary dressing of the wound. Stevenson says that such wounds are apt to give rise to septic discharges. Probably in these cases the vitality of the parts is so lowered that the tissues fall an easy prey to pyogenic micro-organisms. Inquiry among the wounded at Santiago showed that pain was largely related to the idiosyncrasy of the individual. Makin* relates, as a striking instance of absence of entire pain, the case of a man shot through the buttock, the bullet then traversing the abdomen. He was unaware of the fact until he found blood on his trousers on undressing, when he exclaimed, "Why I have got this bloody dysentery." It is related that he died in thirty-six hours.

(2) *Shock.*—Constitutional shock without special tendency to loss of consciousness is generally present. The evidences of shock are most marked in the facial expression. Mr. Harold Schwartz was able by the expression of the face alone to distinguish the cases requiring immediate attention after battle. Before Santiago, in the cases of Mauser wounds from the Spanish rifle, the greatest amount of shock followed hits in the upper part of the femur, the spinal cord, and viscera. Although local shock, as shown by experimental evidence, is much less from reduced-calibre bullets, the assertion on the part of certain observers that men wounded would advance after being hit a number of times was not true of the wounded in Cuba. As a rule to which there were few exceptions, when hit, a man fell back.

(3) *Primary Hemorrhage.*—Primary hemorrhage which threatens life, from gunshot, may be divided into two kinds, internal and external. Of the internal variety, that resulting from injury to blood-vessels in the interior of the trunk, not very readily accessible to surgical aid, is said to cause the majority of deaths on the field of battle, although no one has yet offered statistics to substantiate such claim. Of the external variety, which might be easily stayed by the surgeon in time to save life, the percentage is not so obscure. Doubtless direct injury to a main vessel like the brachial or femoral by a bullet of large calibre, ends fatally in the majority of cases in battle. The cases of this character seen by the surgeon in time are generally acknowledged to be very few compared to the whole number of wounds. According to Longmore they constituted but 3 per cent. in the Crimea. Otis places the number at .05 per cent. in our Civil War. Aside from the internal and external kinds of hemorrhage in which life is immediately threatened, hemorrhage in gunshot wounds is not of special consequence. Much speculation has been indulged in by writers upon the supposed influence of the new high-velocity projectiles in causing additional hemorrhage in wounds hereafter. Happily the apprehensions in this quarter have not been realized. Speaking of the external variety which comes within the opportunity of the surgeon to correct, out of 1,400 wounded in the Santiago campaign the vast majority of which were inflicted by the Mauser bullet, no death took place from this cause nor was a single ligation necessary. The evidence from South Africa is in keeping with our observations in Cuba. Makin† states that hemorrhage was rarely of a dangerous nature except when the larger visceral vessels were involved. From limb wounds the general tendency was to spontaneous cessation of hemorrhage. The English surgeons had ample opportunity to observe this point in over 18,291 wounded exclusive of 4,355 deaths, occurring on the field.‡ Lesion of vessels without tendency to fatal primary hemorrhage from reduced calibre bullets is one of the interesting revelations from this projectile that will be taken up later.

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* "Experiences in South Africa," 1901. † *Op. cit.*
‡ American Medicine, vol. ii., No. 6, 1901.

(4) *Thirst.*—This symptom is of no special importance.

(5) *Lodgment of Bullets.*—With low-velocity weapons like pistols, and the old-fashioned smoothbore guns, the lodgment of the missile is very common. The development of higher velocities has done away with this complication very largely except in long range firing and in those instances in which the momentum of a projectile has been lessened by striking or traversing objects in its line of flight. The number of cases of lodgment in the Santiago campaign was surprisingly large, being about ten per cent. on the side of the United States troops. The Spanish surgeons as well had occasion to wonder at the frequency of lodgment of our bullets in their men. Still when the nature of the field was taken into consideration the cause was readily understood. The Americans had to advance through a country rich in jungle-like vegetation so that the remaining velocity of the projectiles of the two armies was very much reduced, thus favoring arrest in the tissues. It is safe to say that a rifle of lower velocity, like the Springfield, would have exhibited a very much higher percentage of lodged balls. This is confirmed by the English surgeons in the Boer War. There were more lodged balls, everything considered, from the large-calibre Martini-Henry and Snider.

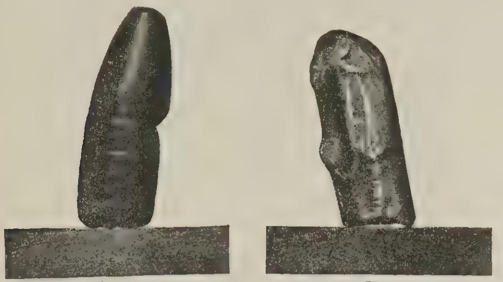
1. 2.

FIG. 2378.—Lodged Bullets. 1, Brass-jacketed ."45 cal. Remington bullet; 2, Filipino ."30 cal. leaden bullet moulded in bamboo stick.

(6) *Powder Burn* is one of the complications of gunshot wounds, at close range upon exposed parts of the body. Grains of powder unconsumed at the moment of ignition lodge under the skin causing tattoo marks, and at relatively close range there is superficial burning of the tissues, by the flame of the ignited powder. Powder burn has received special consideration of late in its medico-legal and pathological bearings. Thus the degree of powder burn is very much modified by the distance of the injured part from the muzzle, the calibre and length of barrel, the amount, standard, and variety of powder, the velocity and direction of the wind, etc. Experiments[*] have shown, as originally pointed out by Dr. D. B. N. Fish, that the burning, scorching, or powder brand as he calls it, is always located on the hammer side of the weapon when the wound has been inflicted by revolvers especially. That is, if the hammer is held up the powder brand will be above the wound of entrance of the bullet; if the weapon is held with the hammer to the left the powder brand will appear to the left of the wound of entrance, if to the right, the powder brand will be to the right of the wound of entrance, etc. The location of the powder brand as described is explained by the action of the recoil upon the point of support, which in the case of a revolver is the hand. This recoil or force tends to cause the weapon to revolve about this point. The ball, which precedes the gases, inflicts the wound of entrance before the barrel has had time to change its direction. By the time the powder gases issue from the muzzle the recoil has partially revolved the weapon, and they necessarily follow the new direction of the barrel which will point above, to the right, or left, as already described. The position of the powder brand has already figured in the courts of justice in distinguishing a suicide from a homicide and vice versa.

The introduction of certain kinds of smokeless powder which produce neither flash nor burning, as shown by our experiments at Fort Logan, tend to destroy the value of the powder brand in medical jurisprudence. Further, if it is true that a homicide can be recognized in the dark by the flash of the igniting black powder from his weapon, the use of smokeless powder will here again furnish negative evidence.

Of the pathological conditions that may arise from the lodgment of grains of unconsumed powder under the skin, so common in so-called powder burn, it is a fact, ascertained by experimentation,[*] that such grains of powder when contaminated by septic cocci purposely or otherwise are not purified by the act of firing. Repeated experiments with black powder purposely inoculated with specific micro-organisms, gave positive results when fired into media and lower animals. The results were not so constant with certain brands of smokeless powders; for instance, the Peyton brand used in our service rifle in 1894, when contaminated with the less resistant organisms and fired into media, gave rise to no growth whatever; nevertheless, when it was treated with Bacillus anthracis and fired into media and animals the results were positive. Taken as a whole the evidence thus obtained tends to confirm the opinion that gunpowder may be at times the medium for conveyance of septic influences like tetanus, malignant œdema,[†] etc. Cases of the former disease reported by H. Nimier of the French Army can hardly be explained otherwise.[‡]

(7) *Multiplicity of Wounds.*—Multiple wounds from the same bullet are recorded in all works on military surgery more as surgical curiosities. The liability to such occurrences have of course increased with the velocity and penetration of projectiles. Now that the velocity of the present service-rifle projectile has recently been doubled and its penetration trebled, multiple wounds are more frequent than heretofore. Instances of this kind from the Mauser bullet were very frequently seen in the Santiago campaign. Thus a man entered the hospital at Siboney with six wounds inflicted by one Mauser bullet, implicating the right shoulder and both breasts. There were a number of instances in which wounds of the body were associated with wounds of the arm or forearm or both, the latter being in a state of flexion at the time of injury. Wounds of entrance and exit in the lower extremity were several times complicated by wounds of the scrotum or penis by the same bullet. Captain —— 7th Infantry received wounds of the face followed by no disfigurement. The projectile, a Mauser, entered the right cheek below the outer canthus, emerged on the nasal side, entered the nose and again emerged at the left side. The linear scars are noticeable only on close inspection. Had these wounds been inflicted by a leaden bullet of larger calibre, the resulting disfigurement would doubtless have been most distressing.

Poisonous Influence of Projectiles.—The experimental work already alluded to demonstrates that there is liability to infection from an infected bullet. It does not necessarily follow that the gunshot wounds inflicted by dirty bullets will suppurate. The virulence of the micro-organism and the resistance of the patient fix the liability very largely. The danger of infection more often arises from particles of clothing or dirty skin carried into the wound by the bullet. Instances of such infection are seldom seen, not because infected material has not been carried into the wound, but more often because the virulence of the organisms so carried is very weak. Formerly the great source of infection lay in the introduction of dirty fingers and probes into all gunshot wounds, a practice reprehensible to-day even under aseptic conditions.

DIAGNOSIS.—The wound of entrance will nearly always give information of the calibre of the bullet; if elongated, whether the angle of incidence with the surface was a right angle or not. When the bullet's remaining velocity is reduced from ricochet or extended range, the so-called keyhole character of the wound of entrance will often suggest the fact. A bullet that sustains deformation by colliding with a hard substance like rock and subsequently inflicts a wound will often fail to give definite evidence of its original diameter, and it is apt to upset thereby the calculations made from the size and shape of the wound of entrance. The appearance of the wound of exit and of the area around it often gives evidence of the extent of damage sustained by a resistant bone. When the wound of exit is two or three times as large as the entrance wound, a bone lesion may be taken for granted. With the employment of armored projectiles we sometimes find smaller multiple lacerations around the exit wound. In the case of close shots these may be due either to fragments of the mantle and lead core of the bullet, when these separate, or to small pieces of bone which, having received the transmittal energy from the projectile, have shot forth acting as secondary missiles.

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[*] Proceedings of the Association of Military Surgeons, U. S., 1895.

[*] *Ibid.* [†] *Ibid.*, p. 170.

[‡] Archives de Médecine et de Pharmacie Militaires, No. 23, 1894.

Bullet extractors, detectors, and probes were formerly used to locate balls, estimate bone lesions, and to trace the direction of the channel made by the missile. It is needless to state that these have given way to the more advantageous methods—fluoroscopy and skiagraphy with the Röntgen ray. The experimental evidence already quoted establishes the fact that there is no such a thing as an aseptic gunshot wound. The shreds of clothing, particles of skin, and the bullet itself infect the channel tract at once. That the infection is generally of a low order, unattended with marked systemic disturbance in the vast majority of cases, is due, first, to the state of quietude in the channel tract; second, to absence of virulence on the part of the organism; and third, to the resistance of the individual. If we violate number one by invading the channel tract with probes, or if two and three are not propitious, suppuration is sure to follow. We will revert to this subject under treatment.

PROGNOSIS.—The prognosis of a gunshot wound depends (1) upon the amount of destructive effects sustained, (2) upon the nature of the anatomical parts traversed, (3) upon the environment, (4) upon the management of the case when it falls under the care of the surgeon, and (5) upon the fatality due to different armaments.

1. Destructive effects are proportional to velocity and resistance on impact; that is to say, when a projectile impressed by a maximum velocity collides with a tissue, like the shaft of a long bone, having a maximum amount of resistance, the result is a maximum amount of destruction. On the other hand a projectile travelling at a maximum amount of speed through tissues like muscle having a minimum amount of resistance will not exhibit destructive effects beyond the area of the channel wound; and conversely, in the case of a projectile travelling at a minimum amount of speed, although it may collide with a resistant structure, the destructive effects will be reduced to a minimum. In estimating the probable amount of destructive effects we should also bear the following in mind, viz.: everything being equal, destruction of tissue increases with the sectional area of the projectile, whether natural or whether it be acquired by ricochet or impact. Projectiles of certain manufacture are purposely made to acquire deformation on impact, and they cause extensive mutilation of tissue when they collide with resistant structures. They are used by sportsmen under the name of express bullets, or soft-nose bullets. They have been used in war under the name of explosive bullets although the name is erroneous, since they do not disintegrate by the action of explosives in them as we find in the shells of field guns or cannons. The soft nose bullet is one that has the armored steel jacket covering the lead core except at the point. On impact the absence of the steel envelope at the point invites disintegration of the projectile so that the core and casing break up into many pieces upon striking resistant bone. Wounds caused by such bullets are murderous in the extreme and not permissible in war by the comity of nations. Their use is tantamount to that of an explosive bullet for hand weapons—a thing which was proscribed by the articles of the St. Petersburg Convention of 1868 (Fig. 2379).

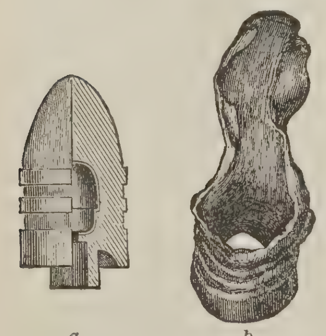

FIG. 2379.—Examples of Explosive Bullets in our Civil War, with Old Calibres. *a*, Gardner's explosive bullet; *b*, fragment of explosive bullet extracted from thigh.

The following illustrations from Dr. Makin's book* are given to show the normal bullets used in South Africa, those that were deformed by ricochet, and also the appearance of the soft-nose bullet before and after impact. Fig. 2380 shows how jacketed bullets may be filed or otherwise tampered with by the soldier on the field, and 3 on the same figure shows an express bullet used in hunting large game. The result with such bullets on impact against resistant structures is the same as that described for soft-nose bullets (Figs. 2375 to 2377).

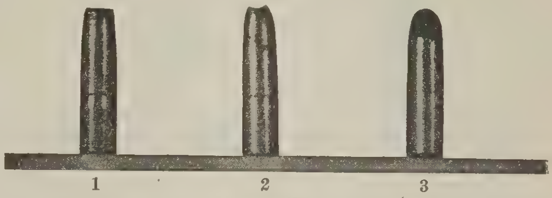

FIG. 2380.—1 and 2 show the steel jacketed projectile with impairment of the steel envelope by filing sufficient to invite deformation on impact; 3, copper-jacketed express bullet, the lead being exposed at the end, used by sportsmen in hunting large game.

FIG. 2381.—Normal Mauser Bullet.

FIG. 2382.—Normal Lee-Metford Bullet. (Makin.)

2. The gravity of gunshot wounds is measured by the nature of the parts traversed. Those of the head, large vessels, spine, and viscera are the most serious.

3. In military practice environment plays a great rôle in the prognosis of gunshot wounds. In the fixed hospitals of civil life, equipped with every necessary appliance, with ample help of the most intelligent kind, the civil surgeon has entire control over his cases at all times; in other words he dominates the environing conditions as they present themselves; whilst, on the other hand, the military surgeon is movable and moving field hospitals.

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* *Op. cit.*

are ever at the mercy of endless conditions far beyond the surgeon's control. The confusion incident to the turmoil of battle renders it impossible to do more than apply a first-aid dressing to a dirty wound. When the battle waxes fiercely there is as much need for help at the front as at the rear, to say nothing of all the labor that is constantly required of the relief corps in transporting the wounded from the fighting line to the field hospitals, oftentimes several miles to the rear. Under these circumstances it is difficult to provide an adequate amount of help to the three places at the same time. Deficiency in help for the wounded is the result—a fault that has existed in large and sudden engagements in all wars. Again, military necessity compels the movement of the wounded so often that the patient is robbed of needed rest, it is a difficult matter to keep his dressings clean, and the dangers of sepsis are thereby magnified. In spite of the best efforts of the military surgeon in times of peace, when he himself has but few opportunities of treating sick and wounded, it is impossible for him to convert the relief corps under his orders into nurses having the same efficiency that one finds in civil life; so that this valuable adjunct to the care of the wounded is far below the standard. If one undertook to picture the reverse of the conditions that prevail around the civil surgeon he could not do so more aptly than by pointing to the predicament of the military surgeon in active campaign. Hence the influence of environment on prognosis.

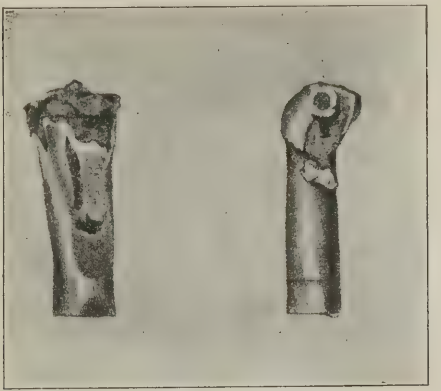

FIG. 2383.—Apical Lee-Metford Ricochets. From Hythe targets. Tendency of cupro-nickel envelope to tear in transverse direction. (Makin.)

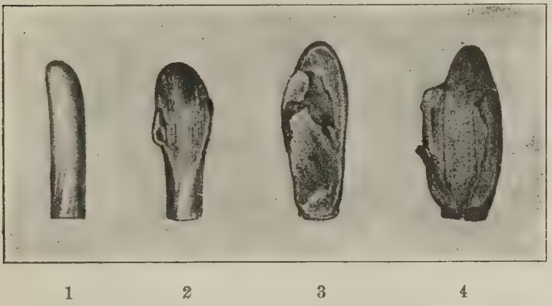

FIG. 2384.—Four Common Types of Lateral Mauser Ricochet Bullets. From left to right. 1, Slipper form; slight broadening and turning of tip. 2, More pronounced degree of form 1, with laceration of the mantle opposite the shoulder of the bullet. This is the weakest spot, for two reasons: the alteration in curve at this position, and the junction of the thickened point of the mantle with the thinner sides. 3, Lateral ricochet involving nearly the whole length of bullet. Rupture of mantle from broadening of core opposite shoulder. 4, Similar lateral ricochet with extensive longitudinal rupture of mantle, the latter being turned out and forming a cutting "flange." (Makin.)

4. The significance of the management of a gunshot wound when it falls under the care of the surgeon was never so thoroughly expressed as by Nussbaum's trite saying: "The fate of the patient with a gunshot wound lies in the hands of the surgeon who applies the first dressing." That this should be done under strict antiseptic precautions goes without saying. More than that, the caution against the unnecessary use of probes should be strictly adhered to. Even in gunshot fractures presenting extensive comminution, there is less danger in a *laissez faire* policy than there is found in an attempt to clear out the wound without adequate preparation. There are certain wounds that need close investigation as soon as possible. This should be thoroughly done, but not before the proper antiseptic precautions are available.

5. The evolution of the military rifle has witnessed some change in the general mortality on the field of battle, but contrary to expectations the mortality has not kept pace with the efficiency in firearms; if anything, it has diminished. This is due partly to the humane character of the armored projectiles, partly to fighting in open order and while lying down. This is well brought out in the subjoined table if we compare the number of killed and wounded to the force engaged in battles with the old armament and in the more recent ones fought with reduced calibres and superior velocities, like the assault on Santiago, and two of the prominent battles of the Kimberley Relief Force, viz.: Belmont and Magersfontein. It should be borne in mind that the armies concerned in the last three engagements were always on the offensive against an enemy well entrenched on heights. The wounds from the artillery arm were less than one per cent. at Santiago, and according to press reports they did not exceed five per cent. at Belmont and Magersfontein, so that the casualties as a whole may be regarded as a fair index of the comparative deadliness of the new military rifle.

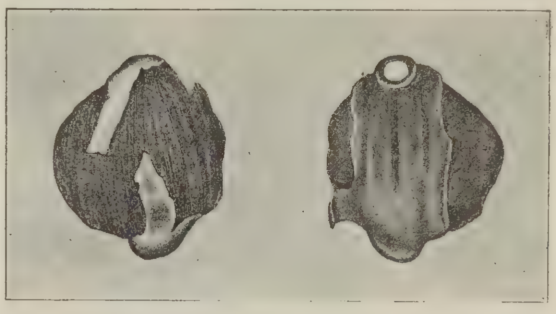

FIG. 2385.—"Disc"-shaped Lateral Ricochet. This form is of little practical importance, as the velocity retained by the bullet is low, and no perforating power would be retained. It is inserted separately in order to complete the series shown in Fig. 2384. (Makin.)

TABLE III.—MORTALITY ON THE FIELD OF BATTLE FROM THE OLD AND NEW ARMS.

	Nation.	Strength.	Killed.	Wounded.	Ratio of killed to wounded.
Waterloo, 1815 ..	British, Hanoverians, and German legions...........	53,284	2,353	7,882	1-3.3
Solferino, 1859 ..	French and Sardinians..............	135,234	2,313	12,102	1-5.2
	Austrians..........	163,124	2,386	10,634	1-4.5
Shiloh, 1862.....	Unionists..........	63,000	1,735	7,882	1-4.5
	Confederates......	40,000	1,728	8,012	1-4.6
Gettysburg, 1863	Unionists..........	117,350	2,834	13,709	1-4.8
	Confederates......	68,352	3,500	14,500	1-4.1
Santiago, 1898 ..	United States forces	11,969	222	1,333	1-6.
	Spaniards	5,140	87	426	1-4.9
Belmont	English............	8,693	58	229	1-3.9
Magersfontein ..	English	11,447	166	717	1-4.3

Occasional Complications.—In former times the complications of gunshot wounds constituted by far the most important clinical picture of this class of wounds; they consisted of inflammation, gangrene, secondary hemorrhage, aneurism, hospital gangrene, pyæmia, tetanus, erysipelas, traumatic delirium, etc. With the exception of those resulting from injury to blood-vessels, the complications that follow gunshot wounds in our day are exceptional. They will be taken up later under the heading of Wounds of the Blood-Vessels, etc.

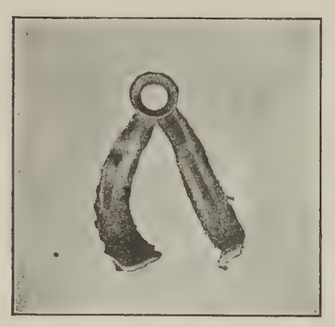

Fig. 2386.—Ruptured Mauser Mantle, to Illustrate the Tendency to Complete Longitudinal Fissuring. (Makin.)

Remote Effects of Gunshot Wounds.—The ulterior and disabling effects of gunshot wounds as treated by authors have reference to conditions that have remained after the healing of the wound has been accomplished. In the past, the amount of invaliding resulting from the ulterior effects of gunshot wounds among the soldiery has been a cause of great expense to the state, and of much pain and protracted suffering to the wounded. Pain and the ills that ensue after the lodgment of foreign bodies have been a fruitful source of the protracted suffering referred to. As one might suppose, the disabling effects are often correlated with the anatomical structure or bodily region involved. A source of remote effects not hitherto described—plumbism from lodged missiles—has recently been touched upon* by Nimier and Laval. In this article they refer to what seems to be a well-authenticated case by Küster and Lewis in *Arch. für Chir.*, t. xliii., p. 221, 1892. Cases of lead poisoning from this source are seen only when the projectile has divided into many fragments, or when the wound has resulted from fine shot that remains embedded in bone, and preferably in the bone marrow and under the periosteum, both of which possess, to a remarkable degree, the property of absorbing materials into the general circulation. In the cases mentioned the symptoms from lead intoxication disappeared as soon as the missiles were removed. Plumbism as a remote effect, already rare, will be very exceptional hereafter in military surgery because of the use of the steel-jacketed bullets, and of the x-ray in diagnosis. The lead core of the latter bullet very seldom separates from its envelope, so that the opportunity for absorption under the most favorable conditions will very seldom occur. The use of the Röntgen ray in diagnosis will point out the location of bullets so exactly that few bullets will be allowed to remain in the tissues long enough to produce any kind of remote effects.

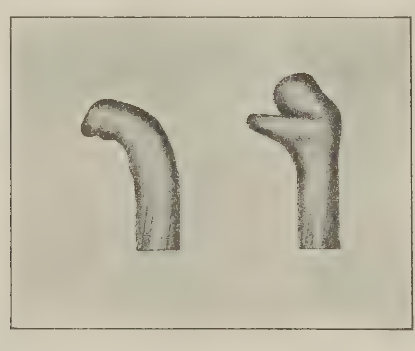

Fig. 2387.—Two retained Mauser bullets which had produced comminuted fractures of the femur of moderate severity. Each has given way at the shoulder, but the mantle developed creases without rupture, and the bullets are correspondingly bent. Both bullets were travelling at a moderate, if not low, degree of velocity. (Makin.)

The amount of suffering from remote effects in gunshot wounds diminished very largely with the introduction of clean surgical methods. Again, the use, in war, of hard steel-clad bullets, that seldom deform or disintegrate on impact with hard bone, have materially curtailed the after-effects in wounds. Projectiles of this class seldom lodge, and when they do, their lighter weight and polished exterior favor permanent encystment with few or no symptoms. It may be stated also to the credit of the reduced-calibre projectiles that they seldom carry clothing or pieces of the accoutrement into the wound track, whereas formerly, with the employment of projectiles of larger calibre, this complication was of common occurrence. Lastly, the use of the x-ray in localizing projectiles and defining the amount of bone injury has played a prominent part in curtailing the remote effects of gunshot wounds. The following skiagrams explain some remote effects before and after operation (Figs. 2390 to 2398).

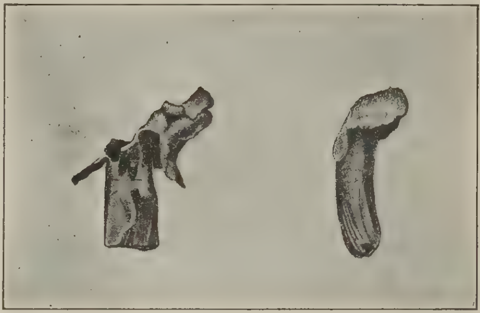

Fig. 2388.—Apical Ricochet Mauser Bullet (see text). The mushrooming of the core is moderate, but the destruction of the anterior part of the mantle very considerable. (Makin.)

General Treatment.—The treatment of gunshot wounds has been very much simplified in late years. The civilian treats them as he would other infected wounds, in accordance with the rules of strict antisepsis. He does not invade the channel tract except for special reasons to be indicated later. In simple uncomplicated gunshot wounds a clean dressing and rest in bed constitute about the necessary measures of treatment. In military practice, when the lack of transport and sudden accessions of large numbers of wounded are thrust upon an inadequate corps of helpers, the medical department resorts to the expedient of furnishing each man, upon going into battle, with a first-aid dressing composed, in our army, of a package five and one-half inches long, one-half inch thick, and two and one-half inches wide. Contents of package: Two antiseptic compresses of sublimated gauze in oiled paper; one antiseptic bandage of sublimated cambric with safety pin; one triangular bandage and a safety pin. The mode of application is illustrated on the bandage. This dressing is

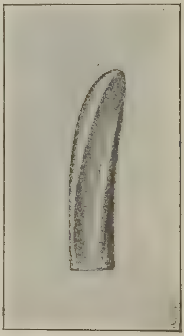

Fig. 2389.—Grooved Mauser Bullet Removed from Anterior Abdominal Wall after Crossing the Ribs. I saw several such removed from the thoracic wall, and am inclined to attribute the grooving to impact with the margin of the ribs. (Makin.)

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* Le Caducée, September 7th, 1901.

usually applied by a comrade or officer who has been instructed in first-aid work by the medical department; or by a member of the hospital corps, and less often by a medical officer. The want of water and time seldom permits more than the application of the dressings without first cleansing the hands of the operator or cleansing the skin about the wound. It is needless to state that a lacerated wound, already infected, dressed in this way will invariably suppurate unless redressed very soon. The fact that the simple wounds, which predominate so largely in war, have heretofore done well under this treatment has caused many observers to attribute the happy results in gunshot wounds to the value of the first-aid dressing. The most that one can say in favor of the practice is that it adds no infection to an already infected wound, which would certainly occur if nothing intervened between the wound and the dirty clothing of the soldier. The simple wounds, and many that included perforations and fractured bones, brought to the Reserve Divisional Hospital, Siboney, from the line near Santiago, exhibited, as a rule, no evidence of suppuration. The loose state in which the dressings were found when they reached us—having oftentimes been imperfectly readjusted by the wounded soldier himself—made it difficult to believe that the happy result was to be ascribed solely to the dressing. These wounds were generally covered by dry blood, and the more reasonable explanation suggested was that healing was taking place under the protective influence of a blood clot. Until we are furnished with something better the military surgeon will have to continue the use of first-aid packages at the dressing stations; later, at the field hospitals, where the appointments are better, wounds are dressed when necessary under such asepsis as field conditions ordinarily permit. Here, also, necessary explorations and surgical operations can be done with some degree of safety. Wounds undergoing suppurative processes can here be thoroughly washed with antiseptic solutions and drained; the dressings can be changed as often as necessary, and with persistence, to the end that suppurative cases shall be kept at the very minimum of number, for once suppuration sets in among the wounded in a hospital the task of preventing its spread becomes doubly difficult, and this is especially true when campaigns are prolonged. The soldiers in prolonged field work lose their normal resistance, while from frequent transmission, pus microbes are ever acquiring virulence as they go from host to host. We are speaking here of field conditions where the military surgeon is not always sure of carrying out an aseptic technique.

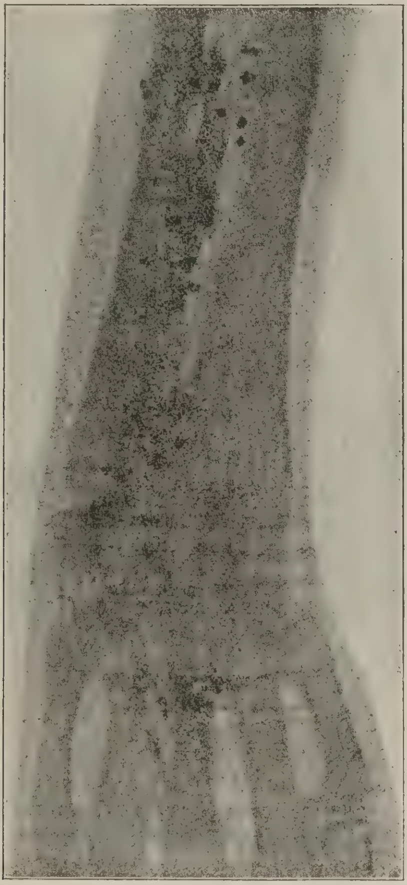


FIG. 2390.—Radiograph. In the case of a marine officer who received a charge of fine shot at close range in the palm of the left hand August, 1900. Wound of exit was on dorsal surface of forearm at junction of lower and middle thirds. During the next four months he had four attacks of lead colic and suffered from plumbism. In December, 1900, the shot was removed. One month later he was free from all symptoms of plumbism. (Nimier.)

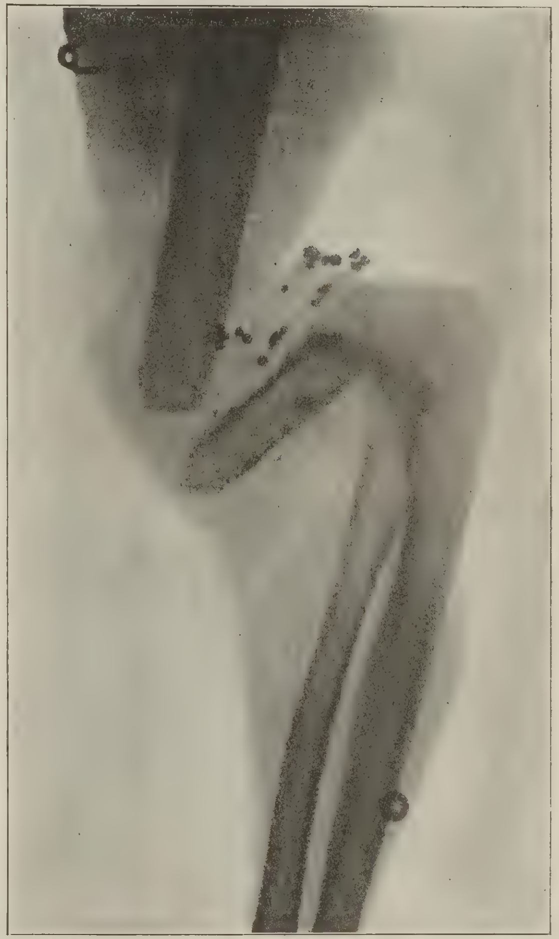
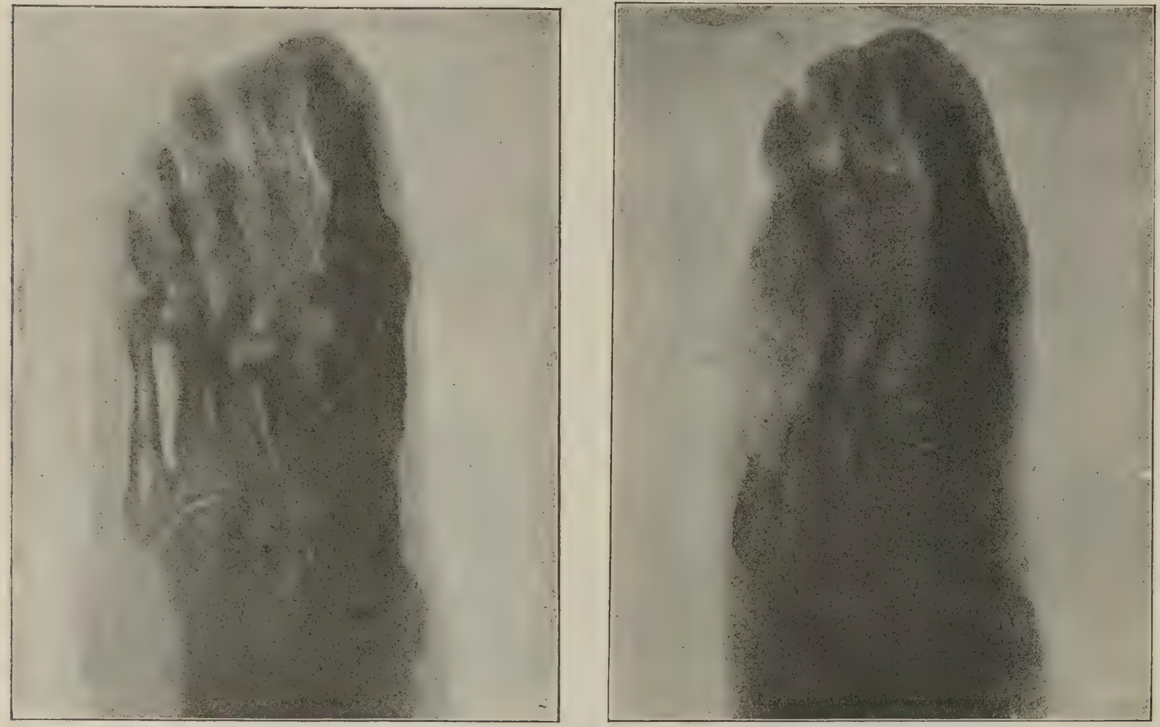


FIG. 2391.—Radiograph. In the case of J. M—— showing ununited fracture of humerus and lodged shot. Wounded June 25th, 1860, by accidental discharge of shotgun within a distance of two feet. Forearm and hand totally paralyzed for three years. Remote effects: flail joint in humerus causing weakness and impairing motion of arm. Radiograph taken October 2d, 1901.

Lodged Balls.—The questions as to whether it is necessary, in any given case, to remove a lodged ball or other missile, and as to what is the proper time for accomplish-



FIGS. 2392 AND 2393.—Radiographs in the case of C. M——, showing the course of a Mauser bullet through the metatarsal bones. Wounded July 1st, 1898, at a distance of 300 yards. The ball ranged transversely across the foot, grating the metatarsal bones in transit. In the process of healing osseous bridges formed uniting the bones. Remote effects: pain at site of wound and limping due to the bony union. Radiograph taken May, 1900. Operation June, 1900. Excision of fourth and fifth metatarsal bones. Result: no pain; the man walks without limping. The second radiograph was taken in August, 1900.

ing this, call for more than a passing notice, at least in military practice. Save in cases of actual necessity (and they are very rare), when time is a factor as it often is in the rush of field practice, bullets should be let alone. An incision for a bullet requires time and an additional dressing, and it exposes the patient to an additional danger of infection amid doubtful surroundings. The morbid curiosity of the laity to find the ball, the restlessness of the patient, and the lack of resolution on the part of the surgeon are only too often exhibited in this late day. At Siboney it was impossible to restrain the surgeons from the practice of cutting out bullets, notwithstanding the strict orders to the contrary, at a time when the dressings were running short, and military necessity was keeping the wounded almost constantly on the move. The necessity and the time for the extraction of a lodged missile are questions which should as a rule be left to the surgeons who are located at those points on the line of communication where the hospitals are fixed and provided with *x*-ray machines. In time of peace the military surgeon should take occasion to explain to the soldiery the evil effects of probing for bullets, and of haste in operating for balls whose location is not exactly defined, and the utter harmlessness that comes from bullets that lie embedded in tissues. If a bullet is lying immediately under the skin, or has already partially protruded through an exit wound, it should be at once removed. Those lying at the bottom of infected tracts should also be removed, as they are generally met with in the special effort to disinfect the wound by irrigation, etc. Those interfering with function or that cause pain by pressure on a nerve should be removed as soon as definitely located; the same is true of projectiles lodged in joints or in close proximity to the joint structure. An effort should be made to remove all missiles of irregular, sharp contour like those which have been deformed through ricochet or by fragmentation, and also pieces of shells, unless they lie in inaccessible regions very near or in the large cavities. Figs. 2400 to 2404, which give skiagraphic views of the head and thorax, illustrate how bullets can remain

FIG. 2394.—Captain K——, United States Army; lodged bullets from whole charge of No. 6 shot four feet from muzzle, entering outer aspect of upper thigh from below upward. There is a distinct bruit emanating from the external circumflex artery, possibly due to shot lodged in or around arterial coats.

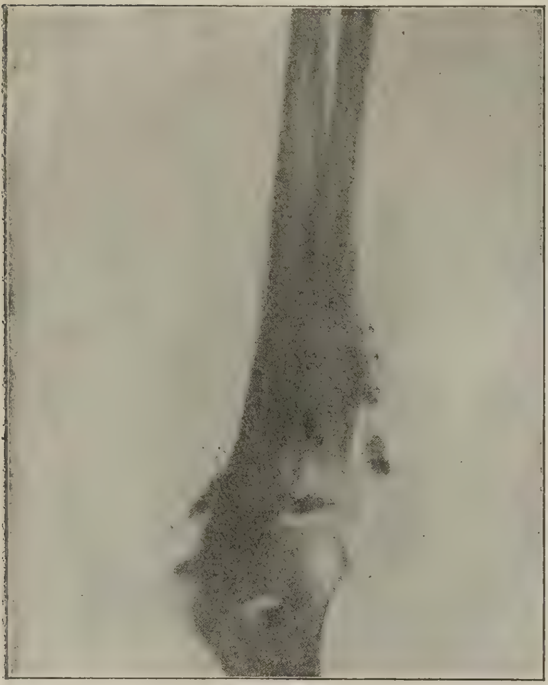


FIG. 2395.

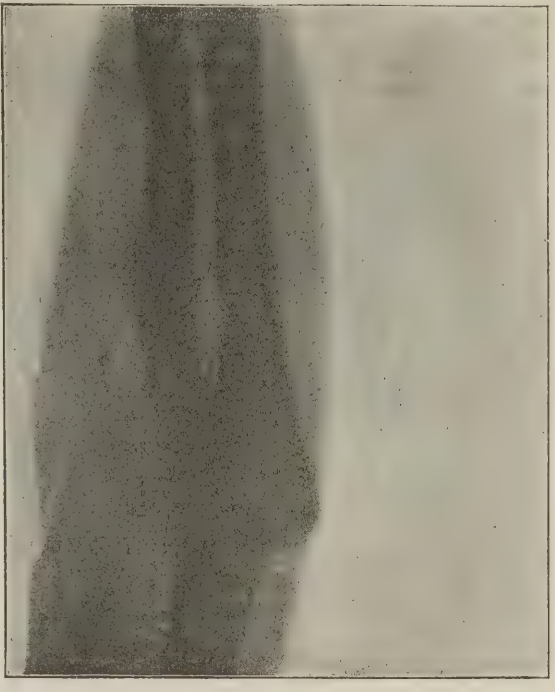


FIG. 2396.

FIGS. 2395 AND 2396.—Radiographs taken from two different directions. Fig. 2395, view at right angles to course of bullet; Fig. 2396, view along course of bullet. In the case of F. F——, showing explosive effects. Wounded October 8th, 1899, by an unknown bullet at a distance of 100 yards. Remote effects: loss of pronation and supination of forearm; partial paralysis of forearm more marked on the extensor surface. (Radiographs taken May 1st, 1900.)

embedded in regions not accessible and yet cause no special harm.

Wounds of the Blood-Vessels.—Of those injuries of blood-vessels which do not terminate fatally before surgical aid can be obtained, the number in war is very small when compared to the total number wounded. It is re-

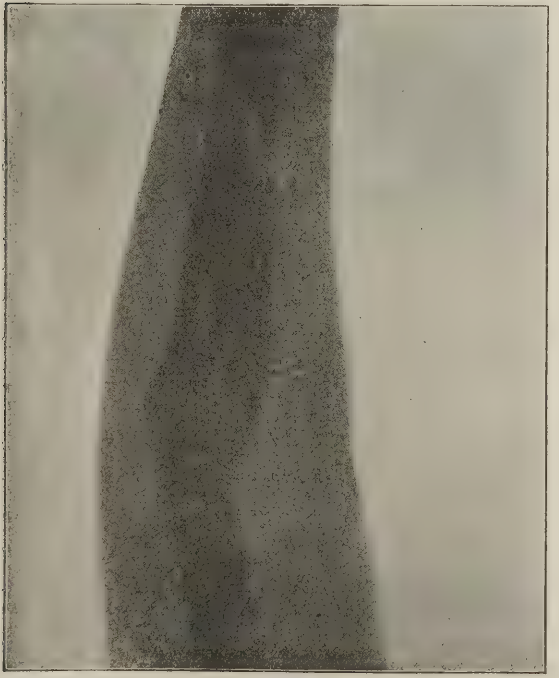


FIG. 2397.

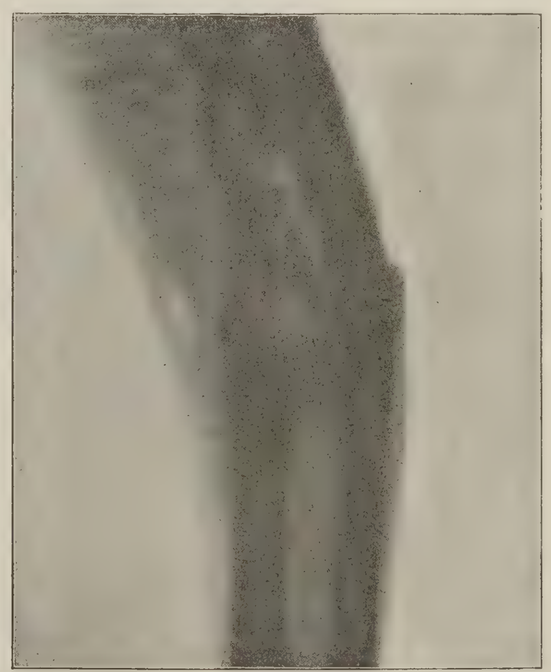


FIG. 2398.

FIGS. 2397 AND 2398.—Radiographs taken from two different directions. Case of D. M——, showing fracture of radius and ulna caused by a large-calibre bullet at a distance of 150 yards. The four fragments united in a solid callus. Remote effects: total paralysis of wrist and hand with loss of sensation over fingers.

lated* that but 27 such cases—.007 per cent.—occurred out of 36,508 wounds in the army of the Potomac from the Rapidan to the James, 1864. In the Crimea (Longmore) of 4,434 wounds recorded, 15 wounds of arteries, or .03 per cent. of the whole, came under observation. The wounds in those days were inflicted by a leaden bullet prone to deformation. There has been much speculation on the part of experimenters as to what would be the effect of the new military rifle upon blood-vessels. We are now in a position to give some facts that have been gathered from the actual conditions in war. Whether the percentage of deaths from fatal primary hemorrhage on the field has increased must still remain doubtful. The superior velocity of the new bullet, its direct course through tissues, and pointed form, increase the chances of its wounding vessels in its path. On the other hand the smaller calibre of this missile, its tendency to preserve its shape unaltered, and the simpler bony lesions which it inflicts, diminish the likelihood that any of the blood-vessels will be wounded by secondary projectiles—either portions liberated from its own substance or fragments of bone to which the bullet itself had communicated its own momentum.

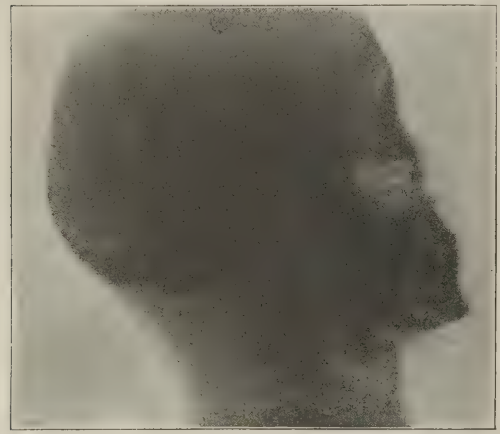


FIG. 2399.—Radiograph. Case of G. W. G——, showing leaden slug lodged in base of tongue. The ball entered behind the left ear Radiograph taken fourteen months after injury. Remote effects: left hemiparalysis of tongue, also loss of taste on left side; loss of hearing in left ear; left optic neuritis; partial ankylosis of lower jaw and painful deglutition.

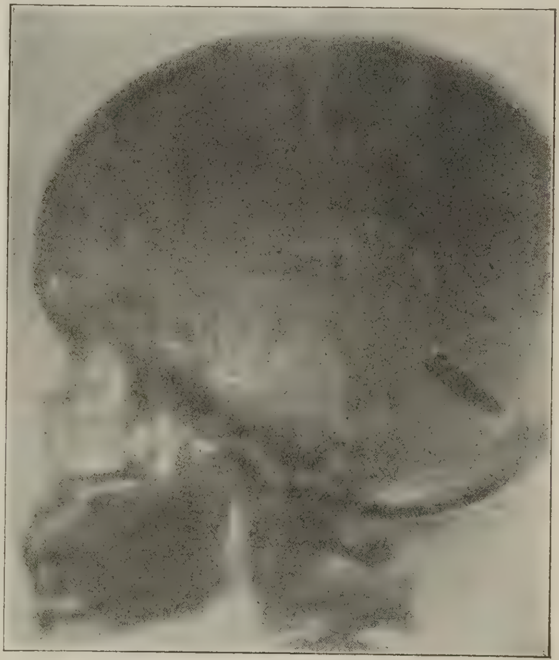


FIG. 2400.—Lodgment of Mauser 7 mm. Bullet (Long Range) in the Brain. Recovery. Private J. G——, 1st Nebraska Volunteers, wounded at Mariboa, P. I., March 27th, 1899. A 7 mm. bullet entered the forehead 2 cm. above the orbital ridge and 3 cm. to the left of the median line, passed directly backward and downward, and lodged about on the tentorium, well within the skull. He was carried one mile to a field hospital, and reached Manila twelve hours after the injury. Complete loss of consciousness for several hours; gradual return to consciousness. In bed four weeks. Primary healing of wound. Returned to quarters June 13th, 1899, cured. First few days of illness were marked by severe pain in head, nausea, and vomiting. More or less pain existed for some weeks, increased by mental or physical exertion, but gradually disappeared. Returned to San Francisco with his regiment in August, quite well. Radiograph taken August 20th, 1899. No history of paralysis other than a slight weakness of right arm and leg, now nearly gone. Some confusion of ideas and slowness of expression existed for a time, but no convulsions or epileptiform seizures occurred. No loss of vision of left eye, but slight ptosis, diplopia, and photophobia were present. Senses of smell and taste more acute on the right than on the left side. Reflexes active; sphincters not involved. Entered mail service, and went back to Manila on duty.

Of fourteen hundred wounded among the United States forces at Santiago by the Mauser bullet there was no instance of a wound of a large vessel requiring ligation on the field. While we have no figures to quote from the South African war, Makin† informs us that "deaths from external primary hemorrhage were rare." Those that recover from injury to blood-vessels form a very interesting class to the surgeon on account of the primary, secondary, and recurrent hemorrhages; as well as on account of the various kinds of aneurisms that are apt to occur in their clinical history. The lesion present in any of these conditions may be contusion or laceration without perforation, partial or complete perforation causing complete division of the vessel. Of the fourteen hundred wounded above mentioned there is no note of either recurrent or secondary hemorrhage. The femoral, the external iliac, and the ulnar were each tied once for diffuse aneurism, the radial and subclavian were tied twice for the same cause, and there were five cases of gangrene that were caused by an injury to blood-vessels and that required amputation. That secondary hemorrhage should be absent in the clinical record of these cases points to the great boon that asepsis has conferred upon the wounded in war. In the days when the surgeon welcomed the appearance of "laudable pus," "no wounded patient was considered to be safe from secondary hemorrhage so long as his wound remained open to suppuration" (Longmore). Disintegration of the arterial coats from septic arteritis was the main cause of secondary hemorrhage in the pre-antiseptic era, and now that we exclude suppuration almost entirely by clean surgical methods we are in a position to appreciate the frequency of secondary hemorrhage from other causes. These causes are in a measure peculiar to gunshot wounds, and they are more apt to be seen in military practice. A projectile, some of its fragments, or spicula of bone, may injure the external coats of an artery at the time of the injury without causing immediate hemorrhage. A few hours or days later, in transport, when rest to the part cannot be secured, hemorrhage occurs by breaking down of the inner coat, unconnected with suppuration. Makin (*op. cit.*) mentions a number of cases of this kind in his South African experiences. He saw only two cases of acute traumatic gangrene, both following gunshot fracture of the thigh. Among the very interesting features of his experience may be mentioned the number of traumatic aneurisms observed "and most frequently of all, perhaps, aneurismal varices and varicose aneurisms. The statement is made of the increase of the number of aneurisms from gunshot wounds in direct ratio to diminution in the size of projectiles employed." We should not forget that our knowledge of the occurrence of traumatic aneurisms with the large calibres was obtained in pre-antiseptic days. We have reason to believe that suppuration, which was so universal in gunshot wounds at that time, played a marked rôle in terminating the cases long before the lesions of vessels referred to had time to develop—say in death from secondary hemorrhage, in ligation of vessels on the proximal side, or in amputation.

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* REFERENCE HANDBOOK OF THE MEDICAL SCIENCES, first edition, vol. vii., p. 18.

† *Op. cit.*

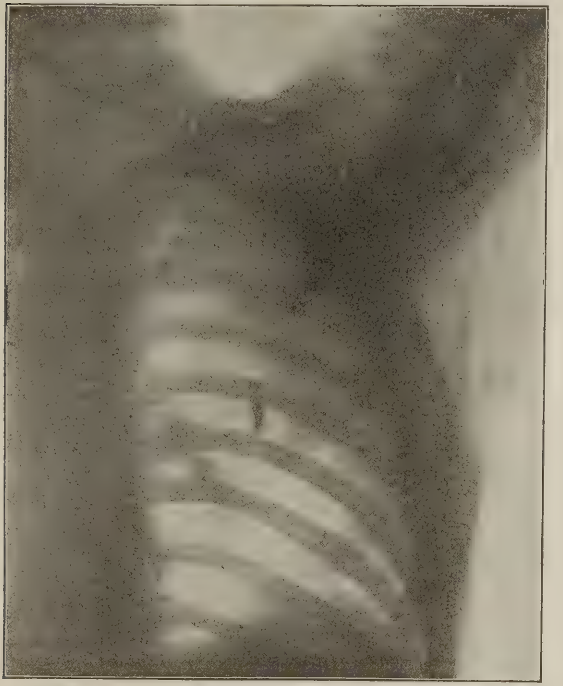

FIG. 2401.—Radiograph Showing Mauser Bullet, Deformed by Ricochet, lodged in Right Back opposite Seventh Intercostal Space.

Until we learn the frequency of aneurisms from the effect of the larger calibres under our present methods of wound treatment, we are hardly in a position to estimate their relative frequency from the smaller calibres under the same conditions.

Injury to nerves has been referred to under Remote Effects of Gunshot Wounds.

Wounds of Joints.—In point of gravity, until recent years, gunshot wounds of the larger joints like the knee and hip, ranked next to those of the larger cavities. For the civil practitioner antisepsis has upset all the statistics of former times, and for the military surgeon antisepsis and the use of armored bullets have operated to make joint wounds among the most humane in war. That this should be so was appreciated by all the military surgeons who entered the experimental field with the new military rifle long before it was put to actual test in battle. As already stated, the destructive effects in a gunshot wound are measured by the velocity of the projectile and the resistance it encounters. The spongy structure of the epiphyseal ends of bones offers a minimum of resistance compared to the compact substance of the diaphyses, and for that reason the lesions of joints even with the high velocity weapons at the proximal ranges are very limited (Figs. 2403 to 2409). The tendency of the armored bullet in passing through the joint ends of the long bones is toward a clean-cut perforation. Fig. 2405 shows that even close by, the tendency to inflict a perforation remains the same. At the remote ranges or from ricochet, when the projectile has lost its balance, it is apt to make an irregular impact, in which case the bone suffers more or less comminution. The joint wounds inflicted by the old leaden bullet of larger calibre are always serious because the projectile meets enough resistance to flatten, thereby increasing its sectional area; the wounds of entrance and exit are larger, rendering more likely the introduction of septic matter; the comminution and fissuring in the bone are more extensive; and, the remaining velocity being always less, the ball is more apt to lodge. If we take as an example wounds of the knee joint as observed in previous wars and compare them with those which occurred in the Spanish-American war, the value of the modern treatment as well as the more favorable lesion inflicted by the jacketed bullet, in point of economy to the State, in saving life and limb, is very striking. A study of all the gunshot wounds of the knee, in war, in which the bones were implicated, gives a mortality of 57.3 per cent.* The Surgeon-General's Report for 1900 records "24 injuries implicating the knee joint, 1 proved fatal . . . after amputation of the thigh. The missile was removed in 4 cases, and amputation was performed in 1 case, the patient recovering." The character of the missile in this group of 24 cases is not stated, but we know that the large majority of the bullets were fired from reduced-calibre rifles. Of 17 cases of gunshot wound of the knee joint reported by the Surgeon-General in 1899, from the Santiago campaign, 14 were returned to duty, and 3 were invalided.

Wounds of the Long Bones.—The injuries inflicted upon the diaphyses by the jacketed bullet do not make so favorable a showing because of the great resistance which compact bone offers to the projectile on impact. At close range the bone is finely comminuted, bone sand being driven into the channel wound and in all directions. The wound of entrance is about the calibre of the bullet, whilst the wound of exit is much larger, showing explosive effects. The bony fragments are apt to be detached from their periosteum and fissures extend vertically above and below the area of comminution. In the mid ranges the fragments of bone are larger and are still attached to the periosteum; the explosive effects are absent and the fissures longer. Guttering of the bone and complete perforations without solution of continuity are not infrequently seen; subperiosteal fractures with little or no tendency to displacement of fragments are also not un-

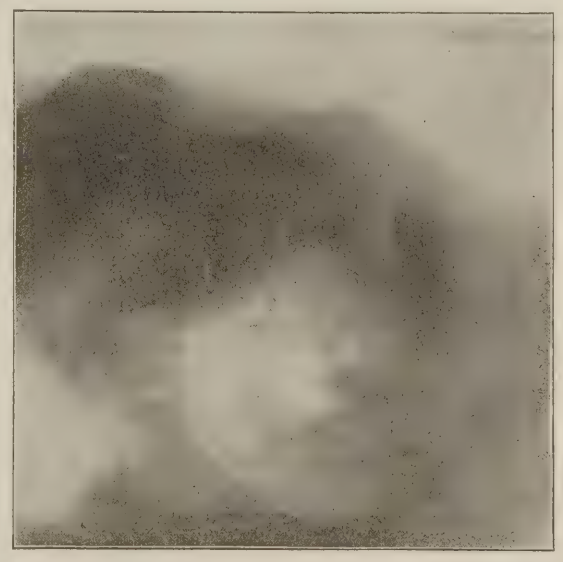

FIG. 2402.—Radiograph. Case of T. H——, showing Mauser bullet lodged above and posterior to the hip-joint. Wounded July 1st, 1898. Radiograph taken October, 1901. The ball entered base first, passing through upper left arm and entering body opposite sixth rib in the mid-axillary line; it passed down to position seen in radiograph.

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* "Wounds in War," W. F. Stevenson, Colonel-Surgeon, British Army.

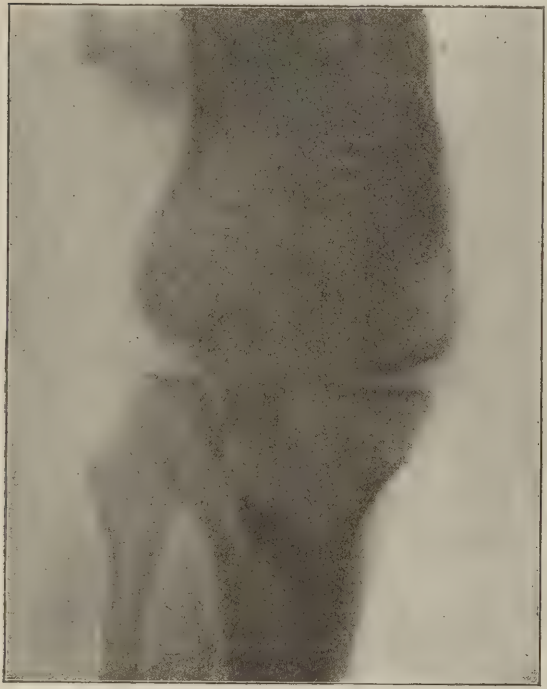

FIG. 2403.

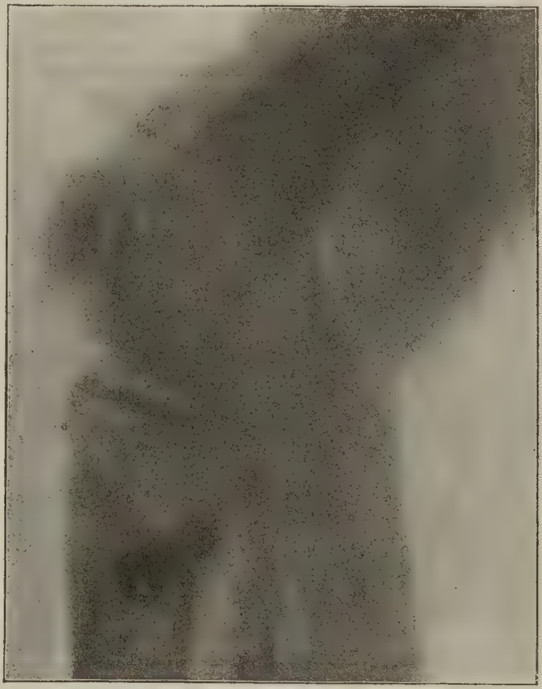

FIG. 2404.

FIGS. 2403 AND 2404.—Radiographs from two different directions. Fig. 2403, antero-posterior view; Fig. 2404, lateral view. In case of E. K——, showing gunshot wound of knee with ball lodged in tibia. Wounded October 23d, 1899, by a Remington bullet which had ricochetted. Distance about 250 yards. The ball entered outer aspect of knee joint 1 cm. above the articular surface, passed down and in through the joint, and lodged in the tibia. Remote effects: chronic arthritis of the joint with weakness and partial ankylosis. The bullet was removed in May, 1900.

common. The results of the treatment of gunshot fractures in the shaft of the long bones bring out more forcibly the value to be credited to our present method of wound treatment than do those which are obtained in any other class of wounds. As stated before, the destructive effects of the old and new bullet are alike severe, and the so-called humane factor so constantly observed in wounds inflicted by the small calibre in other regions is absent in, for instance, the case of the femur. Six thousand five hundred and seventy-six gunshot fractures of the femur in the Civil War gave a mortality of 46.2 per cent., upper third 49.7 per cent., middle third 46.1 per cent., lower third 42.8 per cent. Of 43 cases reported in the annual report of the Surgeon-General, United States Army, for 1900, in which 16 are known to have occurred from small-bore bullets, 11 were returned to duty, 5 died, and the remainder were discharged from the service, a few still remaining under treatment. It is apparent, therefore, that

TABLE IV.—NUMBER, REGIONAL DISTRIBUTION, AND MORTALITY OF GUNSHOT WOUNDS IN THE WOUNDED WHO CAME UNDER TREATMENT IN THE AMERICAN CIVIL WAR AND THE SPANISH-AMERICAN WAR.

	Seat and character of injury.	Number of cases.	Percentage.	Per cent. of all wounds.		Recoveries.	Deaths.	Undetermined results.	Per cent. of fatality.
	Head—								
Civil War	Flesh wounds	7,739	64	3.14	4.9	6,573	2,676	2,480	28.93
	Fractures	4,350	36	1.76					
Spanish-American War.	Flesh wounds	40	56	2.74	4.86	42	18	2	26.09
	Fractures	31	44	2.12					
	Chest—								
Civil War	Non-penetrating	11,996	59	4.87	8.23	13,921	5,373	970	27.85
	Penetrating	8,268	41	3.36					
Spanish-American War.	Non-penetrating	61	54	4.18	7.82	101	13	0	11.40
	Penetrating	53	46	3.64					
	Abdomen—								
Civil War	Non-penetrating	4,748	56	1.93	3.43	3,455	3,293	1,600	48.80
	Penetrating	3,690	44	1.50					
Spanish-American War.	Non-penetrating	20	31	1.37	4.39	35	29	0	45.31
	Penetrating	44	69	3.02					
	Upper extremities—								
Civil War	Flesh wounds	54,801	62	22.29	35.68	8,090	5,608	2,095	6.54
	Fractures	32,992	38	13.39					
Spanish-American War.	Flesh wounds	289	67	19.84	29.44	426	1	0	.0023
	Fractures	140	33	8.91					
	Lower extremities—								
Civil War	Flesh wounds	59,139	68	24.06	35.15	73,665	11,813	935	13.82
	Fractures	27,274	32	11.09					
Spanish-American War.	Flesh wounds	432	77	29.69	38.57	555	9	0	1.60
	Fractures	130	23	8.91					

the general mortality has dropped from 46.2 to 11.1 in favor of antisepsis. At the present time the death rate of this class of wounds increases as the injury nears the greater trochanter, just as it did in the preantiseptic era From the Anglo-Boer war, Makin reports 32 fractures of the shaft of the femur. Of these 18.7 per cent. needed amputation, 15.6 per cent. were fatal. The missile noted was principally the jacketed bullet from the Mauser rifle.

Wounds of the Head.—Gunshot wounds of the head are usually divided into flesh wounds and fractures. The latter are necessarily very fatal. In the Civil War the fatality among all head wounds that reached the hospitals was 28.93 per cent. The fatality of the same class under similar conditions in the Spanish-American war was about the same, 26.09 per cent. The figures concerning the relative number of the two are shown in the preceding table.*

The figures illustrate the frequency of glancing shots with the slow-velocity leaden bullet of the Civil War as compared to their infrequency with the high-velocity steel-jacketed bullet in present use. The latter as a rule travels in a straight line from the point of impact, being seldom deflected from its course by resistant bone. The relative increase in the number of fractures from the use of the modern military rifle augments the fatality in head wounds, so that the humane features attributable to this weapon already referred to do not apply to wounds of this region. These results were foretold by the experimenters before the opportunity to observe the effects of the new arm in the actual conditions of war had presented itself.

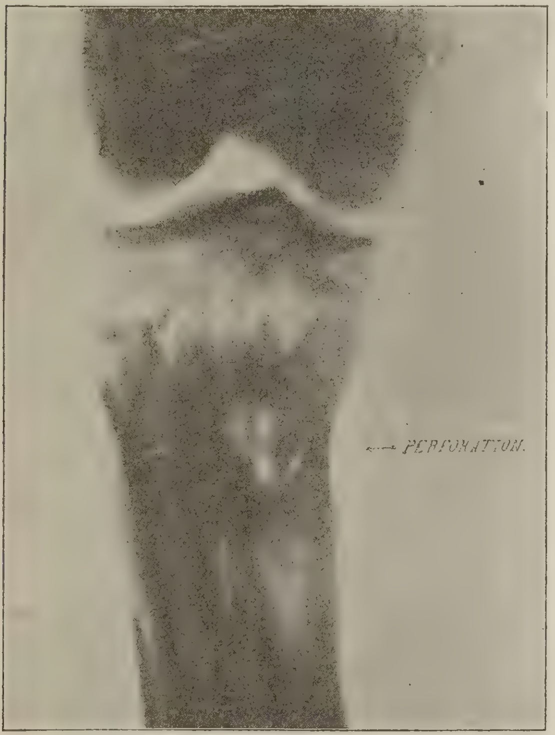

FIG. 2405.—Radiograph. In case of W. K——, showing perforation of upper end of tibia. Wounded June 25th, 1899, by a Krag-Jörgensen bullet at a distance of 10 feet. The fracture extended up into the knee joint, as shown by the escape of synovial fluid after injury. Radiograph taken six months after injury. Remote effects: slight weakness and pain at site of wound.

Stevenson (*op. cit.*), writing in 1897 upon the proportion of flesh to fractured wounds of the skull, states as follows: "In future wars the proportion will be very different. Omitting indirect and grazing hits, almost every bullet which hits the skull, up to a range of 2,200 yards, will perforate it, and at about 2,900 yards they will penetrate and remain lodged. The destruction produced in the skull and brain by modern bullets is so extreme, even at long ranges, that comparatively few patients will survive long enough to reach the field hospital for treatment, and for the large majority of those who do, treatment will be unavailing."

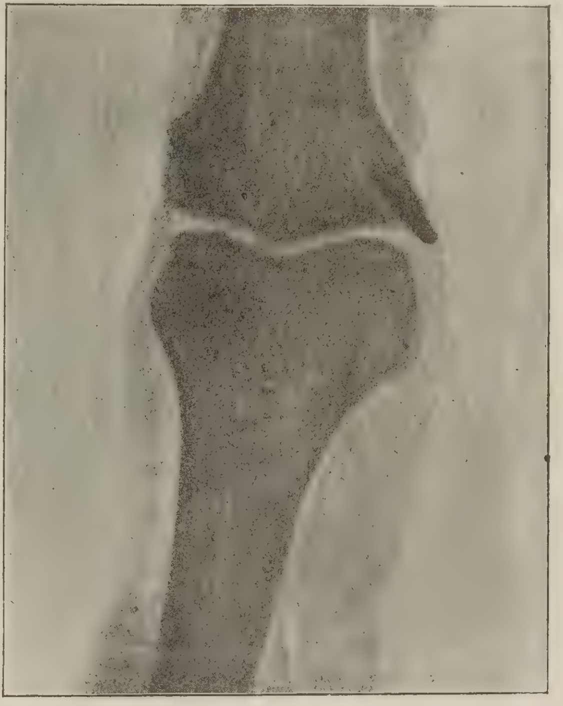

FIG. 2406.—Case of Lodged Bullet in Knee Joint. A cavalry man was shot by a ricochet bullet which passed through the left thigh and into the right knee joint, where it lodged. When admitted two days later he was found to be in the second week of typhoid fever. The bullet was removed six weeks after injury. The adhesions were broken up. Result: the joint became perfectly sound and useful. (From "A Civilian War Hospital.")

Concerning the results in the Anglo-Boer war, Makin (*op. cit.*) states: "injuries to the head formed one of the most fruitful sources of death both upon the battlefield and in field hospitals." He mentions some "sensational immediate recoveries" among head wounds, and they doubtless were of the character of those noted by us in the Santiago campaign, viz., oblique perforations of the skull cap involving the brain tissue at a limited depth. The gunshot fractures about the base and those running deeply through the brain from base to vertex or vice versa were uniformly fatal. Of 68 cases of gunshot fracture which were reported in the Surgeon-General's Report for 1900, and which occurred during the two preceding years, 54.4 per cent. ended fatally as against 59.2 per cent. out of 2,514 cases noted in the Civil War. Unlike wounds of other regions those of the head, unless properly treated at once, undergo suppuration, a fact which is not surprising when the amount of dirt overlying the scalp is considered. The surgeons in the Cuban and South African campaigns are unanimous in recommending early and free exploration of all cases of fracture of the skull by gunshot. The aim should be to relieve pressure and to rid the wound of all dirt and loose pieces of bone as soon as possible.

Wounds of the Spine.—Gunshot injuries of the spine are the most fatal in war hospitals. Their gravity increases as the wound approaches nearer to the head.

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* Borden: "Military Surgery"; Prize Essay, Proceedings Association Mil. Surg., 1900.

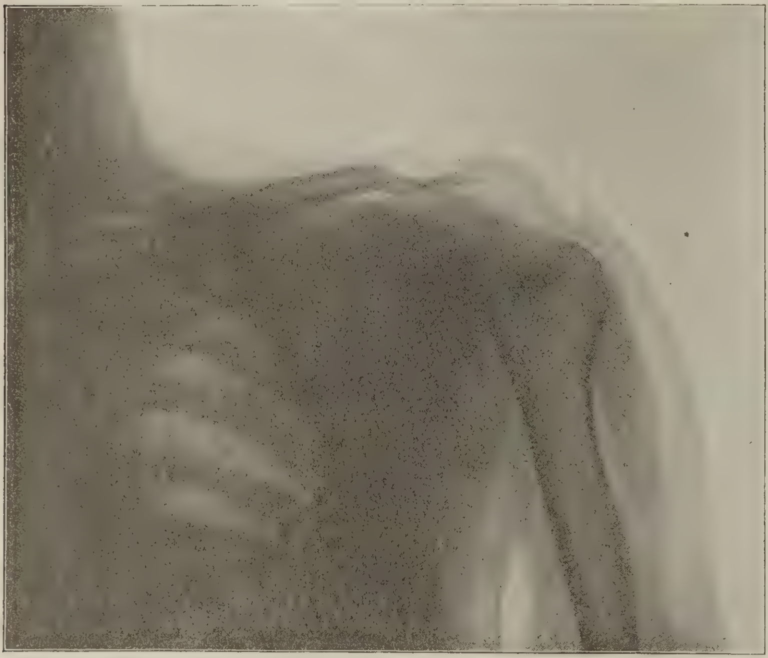

FIG. 2407.—Radiograph in Case of L. E. K——, Showing Gunshot Wound Involving the Shoulder Joint. Wound inflicted by a Mauser bullet at a distance of 6 feet. The ball passed directly through the shoulder joint, grooving the upper end of the humerus and emerging over the inner border of the scapula. Remote effects: paralysis of deltoid muscle and general weakness and impaired nutrition of the arm.

Otis, in the records of the Civil War, places the mortality in the cervical, dorsal, and lumbar regions at 70 per cent.; 63.5 per cent.; and 45.5 per cent. respectively. The fatality increases if the injury involves at the same time any of the organs in the neighboring large cavities. If the spinal column alone is injured the gravity of the case will depend upon the fact whether or not the cord is also implicated. In fractures of the body or laminæ, the cord is nearly always involved, and, sooner or later, the termination is in death. Injuries of the spinous and transverse processes are less likely to be attended with lesion of the cord, and this class therefore constitutes the bulk of recoveries among the wounds of the spine. Beyond the fact that the foyer of comminution is more restricted, as a rule, with the small-calibre bullets, wounds by them are as severe in their results as those from the large calibres of olden times. When the spinal medulla is implicated, Makin, in his experiences in South Africa, states that "the cases were proportionately the most fatal of any in the whole body to the wounded who left the field of battle or field hospital alive."

Wounds of the Chest.—The loss of life in battle from penetrating gunshot wounds of the chest, inflicted by bullets of the larger calibres, has been very great, varying between 62.5 per cent. in our Civil War and 91.6 per cent. among the French troops in the Crimea. When we consider the subsequent mortality from secondary involve-

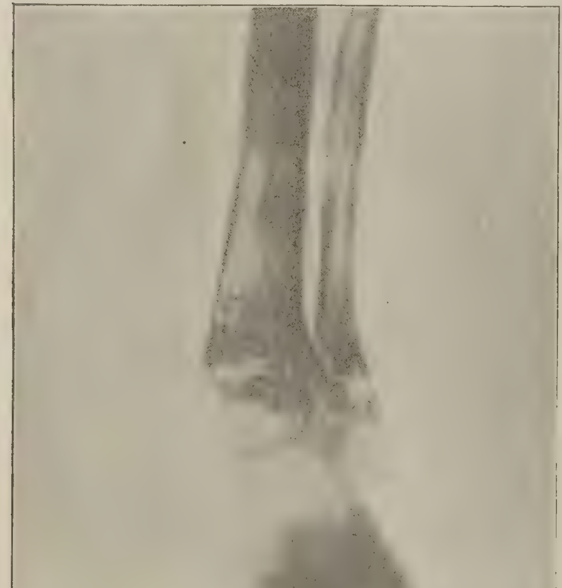

FIG. 2408.—Radiograph, showing track of bullet through lower ends of tibia and fibula. Wound was caused by a Mauser bullet February 2d, 1901, at a distance of 100 yards. The fracture extended down into the ankle joint. Remote effects: osteomyelitis of fibula; partial ankylosis of ankle; unable to bear any weight on foot. Radiograph taken nine months after injury.

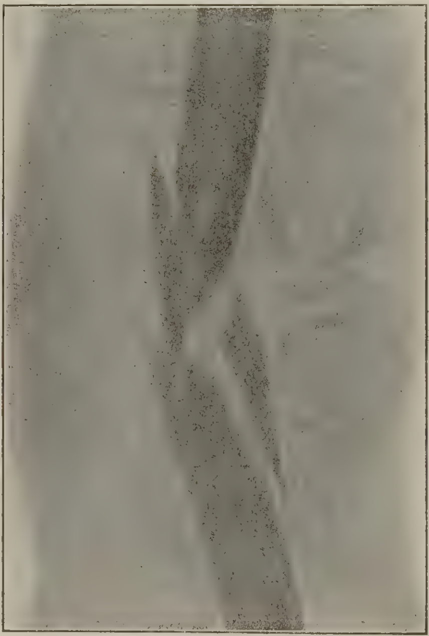

FIG. 2409.—Comminuted Fracture of the Humerus. Range about 300 Yards. The wound track took a directly antero-posterior course. Impact rectangular. The musculo-spiral nerve was completely divided. The plate affords a good example of the so-called "butterfly" fracture. Two long doubly wedge-shaped lateral fragments, and pointed extremities to both main fragments, are shown. The fracture healed well, with the deposition of a large mass of provisional callus. The musculo-spiral nerve was united by suture some three months later. (See Butterfly fracture, Fig. 2365, caused experimentally.) (Makin.)

ments like pneumonia, pleuritis, phthisis, etc., the mortality in the end is little less if any than that recorded in penetrating wounds of the head and spine. Happily, the humane features of gunshot wounds inflicted by the steel-clad bullets, as foretold by the experimenters, have already been satisfactorily shown in the Spanish-American and South African wars. If we recall the factors that are correlated to destructive effects in wounds—viz., velocity, sectional area, and resistance on impact—we find that the last two factors (sectional area and resistance) favor a limited amount of destructive effects. Since the Crimean war the calibre of the military rifle has been reduced nearly one-half. As to resistance, the lung, composed of elastic tissue and filled with air, invites but little lateral displacement; hence the great diminution in the mortality of this class of wounds. Of 198 cases of penetrating gunshot wounds of the chest (reported by the Surgeon-General of our army) which occurred during the years 1898 and 1899 in Cuba, Porto Rico, the Philippines, etc., 55, or 27 per cent., ended fatally. As to the results in South Africa, where the experience of the medical department was much larger, Makin states that "wounds of the chest furnished the most hopeful class of the whole series of trunk or visceral injuries. Cases of *wounds of the heart and great vessels*" [the italics are ours] "afforded the only exceptions to an almost universally favorable course, both as regards life and the non-occurrence of serious after-effects." Notwithstanding the favorable outcome of chest wounds, as inflicted by the new armament, it should be borne in mind that the clinical history of these cases is apt to be accompanied by complications like hæmothorax and pyothorax. The apparently trivial nature of the wound, in the majority of those who lived to reach the field hospitals, was exemplified at the Reserve Divisional Hospital at Siboney, in men who, though shot through and through a few days before, could be kept prone in bed only by the most watchful care over them of the nurses. Doubtless a number of the sequelæ observed afterward in these men* was due to imprudence on the part of the patients in disregarding the instructions to keep quiet.

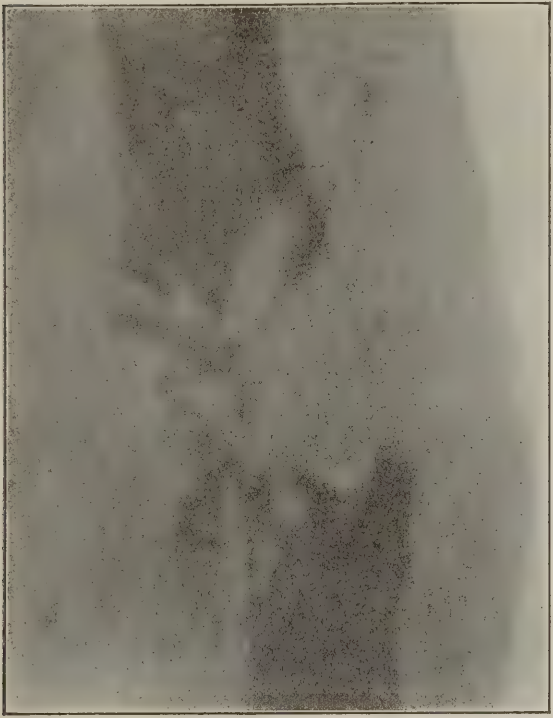

FIG. 2410.—Comminuted Fracture of the Humerus. Range 50 yards. Velocity extreme. Impact somewhat oblique. The bullet entered anteriorly about three inches above the elbow crease. The wound of exit was on the inner aspect of the arm and explosive in character; it still measured four inches by two inches three weeks after the injury was received. The wounds suppurated locally, but at the end of six weeks fair union of the bone had taken place and the wound of exit had contracted to a sinus. The musculo-spiral nerve was concussed, but not divided. The skiagram was taken three weeks after the reception of the injury. (Makin.)

As relating to this point it may be stated that Makin observed in South Africa, in the early part of the campaign when the patients were treated near the place of battle, and required but little subsequent transportation, that hæmothorax occurred only in probably thirty per cent. of cases. Later on, when it became necessary to transport the wounded for much greater distances—requiring in some instances journeys of two or even three days,—at least ninety per cent. of these patients "suffered with hæmothorax of varying degrees of severity." In referring to the only case of empyema seen by him during the whole campaign, he informs us that it followed the removal of a lodged bullet, and that the additional wound doubtless proved the source of infection because of the difficulty of maintaining asepsis in wounds treated under

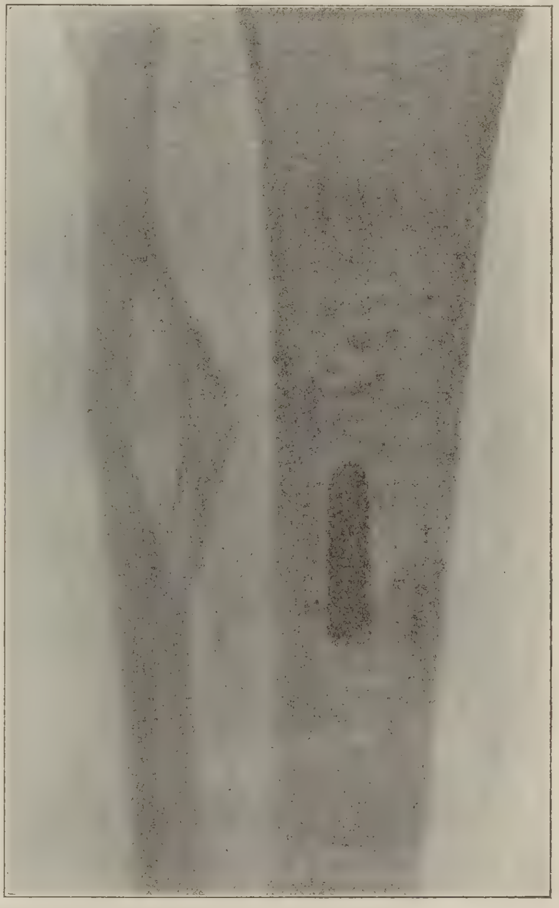

FIG. 2411.—Spurious Perforation of the Fibula. Moderate range about 1,000 yards. The injury was caused by an 8 mm. bullet, which entered base foremost and lodged in the calf. The fracture is really an incomplete stellate form, two well-marked transverse fissures extending from the point struck. The position of the bullet suggests its entry into the limb base foremost, and, as it is retained, a low velocity may be assumed. (From Makin's "Surgical Experience in South Africa.")

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*Greenleaf: "Gunshot Wounds of the Lungs." N. Y. Med. Journal, vol. lxx.

such questionable surroundings as one encounters in the field. The moral which he draws from the circumstance is one to which we have already adverted—*remove no lodged missiles in the field save for exceptionally good reasons.*

Wounds of the Abdomen.—Penetrating gunshot wounds of the abdomen, under the expectant plan of treatment, were the most fatal of the regional wounds in both military and civil practice; the mortality ranging between ninety-five and ninety-nine per cent. Under a wise selection of cases and the employment of expert technique in operating, the statistics of fatality have been reduced by nearly a half in civil hospitals, while on account of unavoidable causes the death rate in military practice, in the field, still remains very high. In civil hospitals, where one finds all the modern conveniences and comforts to promote the well-being of the wounded, and where, further, the surgeon, almost from the moment of the receipt of the injury, holds absolute sway over his surroundings, the mortality, as shown by Grant's* statistics of operative cases, amounts to 52.5 per cent. in a series of 253 cases. Morton, of Philadelphia, reports 138 deaths after operation, or a mortality of 58.9 per cent., out of 234 cases collected from various sources in this country and Europe. Coley's statistics show a death rate of 53.8 per cent. in a series of 39 cases operated upon during the first twelve hours after injury; and a mortality of 77.2 per cent. in 22 cases operated upon at a later period. In military practice, in the conditions that obtain in active campaign, as already stated, the mortality has been very large, the death rate in the Crimea for the French and English troops being respectively 91.7 per cent. and 92.5 per cent. In our Civil War the fatality reached 90 per cent. When we remember that in many of those who are thus reported to have recovered, the abdomen was in reality not perforated, we are forced to the conclusion that the high mortality given would probably have to be made still higher if it had been possible to consider only perforative cases.

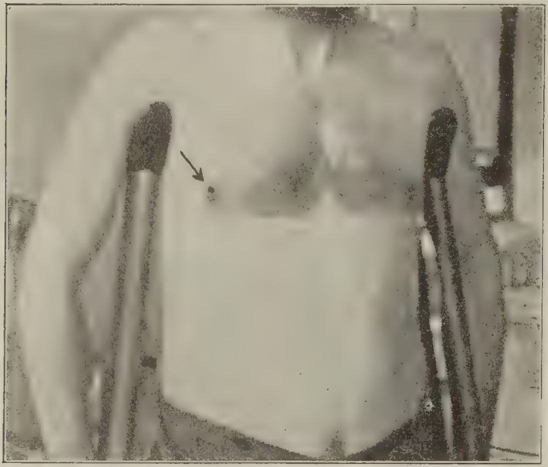

FIG. 2412.

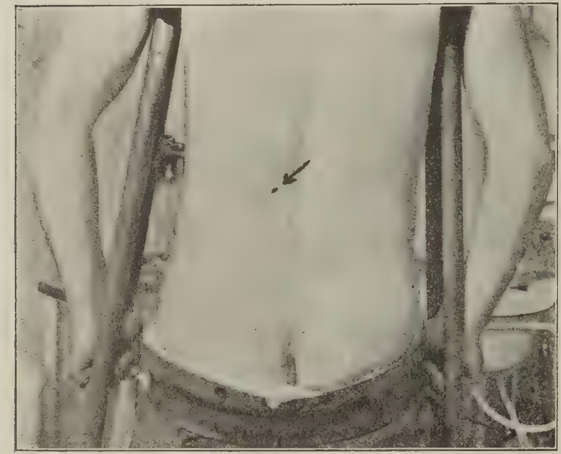

FIG. 2413.

FIGS. 2412 AND 2413.—2412, Wound of Entrance; 2413, Wound of Exit. A. F——, wounded in battle of Calamba, P. I., July 30th, 1899, by a Mauser bullet at a distance of 250 yards. Bullet passed through lung and liver, and injured spine. Remote effects: partial paralysis of left leg and neuritis of nerves of lower leg.

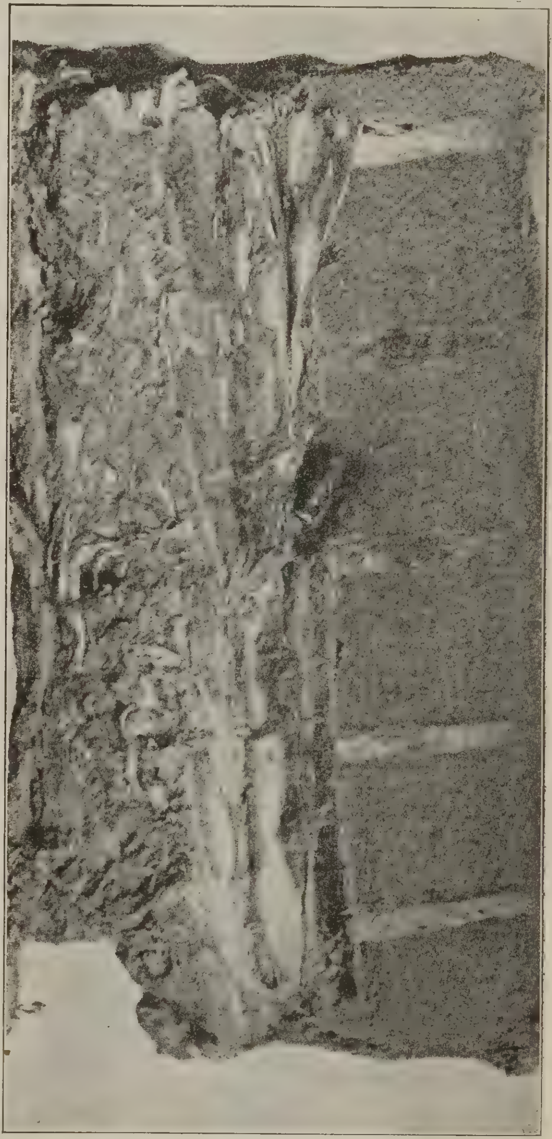

FIG. 2414.—Portion of Spinal Column, Showing a Lodged Bullet which had Divided the Spinal Cord. (Makin.)

The encouraging results obtained in civil hospitals gave the military surgeon hope that his results might be

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* Va. Medical Semi-Monthly, January 12th, 1900.

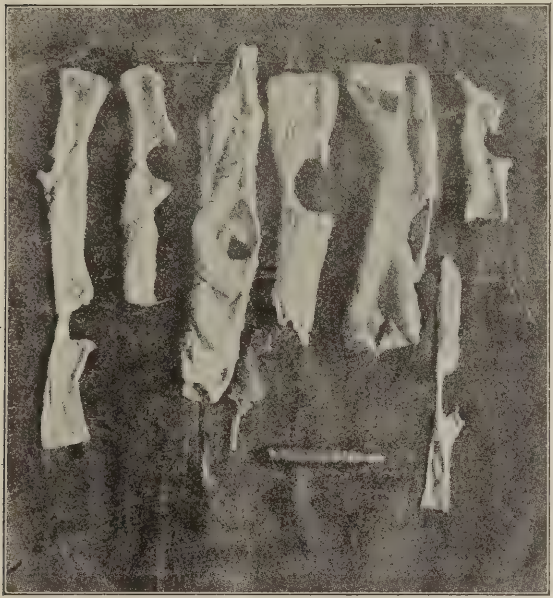

Fig. 2415.

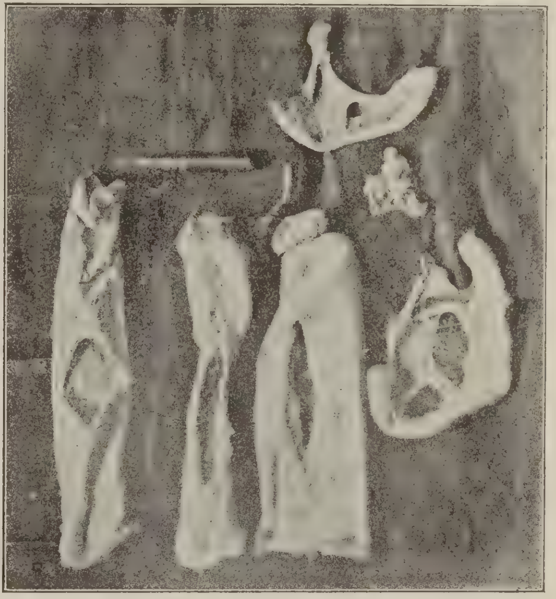

Fig. 2416.

Figs. 2415 and 2416.—The lesions of the intestines were inflicted on dogs by the .30 calibre Krag-Jörgensen bullet at 300 yards. (Griffith.)

nearly as good. These expectations, as the sequel shows, were not realized. Of 116 cases reported in the Annual Report of the Surgeon-General of the army for 1900,—cases which occurred in the Spanish-American war and during the Philippine insurrection,—there were 81 deaths, or a mortality of 70 per cent. The evidence of perforation was doubtless based upon the position of the apertures and the course of the ball in a straight line between these. It is fair to state that, of the 30 per cent. who recovered, the large majority sustained no injury to the intestine. The experiences of Makin in South Africa lead him to the belief that perforating wounds of the small intestine are very fatal*—"every patient in whom the condition was certainly diagnosed died." The table given below includes only those cases which survived longer than twenty-four hours, upon six of whom he operated. It will be seen that the prognosis varies largely with the anatomical structure involved in the perforation. It should be noted that of the ten cases of *possible* perforation of the small intestine there were ten recoveries, a fact that goes to show that in all probability few if any of them were perforative cases at all; and that, of the five cases of perforation of the "small intestine certain," death was the result in every instance. As far as prognosis is concerned, gunshot perforation of the small intestine, without operative interference, is as fatal to-day on the field of battle as it was during the Crimea. Some rare cases of recovery with few symptoms, cited by Makin, make it difficult to conceive how a projectile could plough its way through the abdomen from one flank to the other without cutting the intestine. Several cases of this kind were seen at Siboney from the line near Santiago, and they go to show that the small-calibre bullet is likely at times to traverse the intestinal area without inflicting injury of a fatal kind. Aside from the small sectional area of the bullet which would favor such an occurrence, it has been suggested that the intestinal lesion is apt to be minimized by fasting. The men before Santiago had been on scant rations for one week, and the remarkable recoveries among abdominal wounds were at the time attributed to the empty condition of the alimentary canal. We know by experimentation that the reverse condition would have been highly favorable to the infliction of extensive lesions. Resistance, among the three factors which conduce to destructive effects,—the other two being velocity and sectional area of the projectile,—is not confined to the compact substance of bone. The most extensive explosive effects are met in cavities filled with fluid or semifluid contents. Griffiths'* experiments upon dogs on the Fort Leavenworth range demonstrate that when all the conditions are favorable, the intestines will show rents varying from two to eight inches in their continuity. Men on the field of battle so wounded do not live to reach the relief stations; they die as a rule where they fell, from shock and internal hemorrhage. In gunshot wounds of the abdomen the vital question at issue is whether or not the wound is perforating in kind. If the evidence points with reasonable clearness to a wound of the former character, the treatment resolves itself into a cœliotomy either for the purpose of exploration or for that of remedying the injury done to the abdominal organs. Whether surgical aid of the latter kind is to be practised will largely depend on the confidence and skill of the operator and the nature of the environment. As stated before, owing to the unpropitious character of the latter, laparotomy on the field or in field hospitals in war has thus far been limited, and the results, when the

Table V.

Viscus wounded.	Number of cases.	Localized secondary suppuration occurred.	Re-covered.	Died.
Stomach certain	2	..	1	1
Stomach possible	1	..	1	..
Small intestine certain	5	0	..	5
Small intestine possible	10	0	10	
Large intestine certain	8	4	4	4
Large intestine possible	4	..	4	
Bladder certain	3	3	1	2
Bladder possible	1	..	1	
Liver	6	..	6	
Kidneys	6	..	4	2
Spleen	3	..	2	1
Total	49	7	34	15

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* *Op. cit.*, p. 448.

* Proceedings of the Association of Military Surgeons, 1893.

practice has been carried out, have been anything but encouraging. Of the three laparotomies done at one of the advanced hospitals before Santiago, the mortality was one hundred per cent. In order to accomplish successful abdominal work in war it will be necessary to use a great deal of forethought, so that the operators may not be hampered by the endless difficulties that are apt to occur in active campaign. It is possible to conceive of a field hospital so thoroughly equipped with material and personnel, and so favored by the condition of the weather, that in it a laparotomy may be performed with about the same safety as is experienced in a civil or fixed hospital. So far, the idea of establishing such a hospital has not been acted upon seriously. The subject is one replete with possibilities. *Louis A. La Garde.*

GURJUN BALSAM.—Wood Oil. A viscid, copaiba-like turpentine, obtained from half a dozen or more majestic Asiatic trees of the genus *Dipterocarpus.** The "balsam" is collected by making deep "boxes" or gashes in the trunk of the tree, scorching them, and fitting a bamboo spout to their lowest parts. The yield is very great, and the drug forms quite an important article of commerce in the East. It is officially recognized by the Indian Pharmacopœia, and extensively used there as a substitute for copaiba. In other countries it is considerably used to adulterate the latter drug.

It is an intensely fluorescent, thick liquid, of a mild, terebinthinous odor, and a bitterish, aromatic taste. By transmitted light it is of a deep sherry color, and perfectly transparent; by reflected light it appears opalescent and greenish-gray. It is soluble in chloroform and the essential oils, but not completely so in alcohol. It consists of thirty or forty per cent. of a mild-smelling essential oil associated with a composite resin, composed of a crystalline *gurjunic acid*, and an amorphous portion. As it is collected from several different trees, its appearance, and also probably its composition, are subject to considerable variation.

Uses.—In India and Asia generally as a substitute for copaiba in the treatment of gonorrhœa, etc., and as a varnish. It is occasionally to be got in this country, but is prescribed only as a novelty. *W. P. Bolles.*

GUTTA PERCHA.—The inspissated milk-juice of *Palaquium Gutta* (Hook. f.) Burck (fam. *Sapotaceæ*). (No longer official in the United States.) This remarkable substance is admitted into the pharmacopœias of most countries on account of the elastic varnish which can be made from it, and of its value in the making of plastic splints in surgery. The plant is a large tree growing, now or formerly, in many parts of Southern Asia, and in the great islands of the Pacific. Gutta percha was first brought into European use in 1842, having been previously employed by the aborigines in the manufacture of knife and weapon handles. From the vicinity of Singapore, where it was previously abundant, from Penang and other accessible places, the tree has been practically exterminated by the wasteful method of collecting its valued product. It still exists, however, in abundance in the Malay peninsula, whence most of the gutta percha now comes, in Borneo, Sumatra, and other places. The method of collection is as follows: The trees are felled and the bark is stripped off, when the milky product beneath it collects upon the surface of the wood, and is scraped off and put into a hollow leaf or other convenient receptacle. This juice quickly coagulates upon exposure to the air, and the putty-like curd is moulded while yet soft into blocks or cakes of various sizes and shapes. It is of a light or medium brown color, often gray upon the surface, sometimes, when nearly pure, white or ash-colored, of a peculiar rubber-like odor, and a rather flexible consistence at common temperatures. At something above 120° F. it becomes very plastic, and may be moulded into any shape and welded, resuming its hardness upon cooling. Ordinary gutta percha is an impure substance, containing inevitably, by the method of its collection, a considerable amount of coarse admixture of vegetable tissue, chips, etc., besides the residues of the evaporation of portions of the liquid juice, imperfectly separated from it in coagulating. It is soluble in chloroform, turpentine, carbon disulphide, etc., but not in water, alcohol, acids, or alkalies. Its purification may be effected by solution in one of the above, or by mixing with hot water and straining. The sheets, in which form it is generally sold for surgical use, are made by rolling it while hot between cylinders.

The principal portion, seventy-five per cent. or so, of good gutta percha, consists of an amorphous white mass or powder having the general properties given above, named *gutta.* It contains, further, from fourteen to sixteen per cent. of *alban*, a light flaky powder soluble in boiling alcohol, and from four to six and a half of *fluavil*, which is rather more soluble than either of the above (Payen).

Gutta percha is employed in medicine only on account of its physical properties. A nine-per-cent. solution of it in chloroform, with ten parts of carbonate of lead added mechanically to carry down coloring matters and impurities, is an excellent protective varnish for abrasions, excoriations, and small wounds, to be used in the same way as collodion. In sheets, from one-eighth to one-fourth of an inch thick, it is to be had of the instrument makers as a splint material. For cases in which there is a good deal of irregularity of surface to be fitted, as in fractures of the jaw, the bones of the thumb or great toe, or the metacarpal or tarsal bones, it is very useful; also in making splints that must be often taken off and reapplied. The form of the splint should be cut about one-fourth larger each way than the desired splint, as it shrivels when softened and when thrown into water at a temperature of about 130° or 140° F. or more. The limb having been prepared by adjusting the parts, shaving, bandaging, etc., as required, the softened splint is laid on the part and quickly moulded by the fingers to the desired form. A bandage where necessary is then applied, and cold water poured over all. When hardened the gutta-percha splint may be taken off, trimmed, and permanently reapplied. If it is desired to piece or weld the gutta-percha, it should be softened by dry heat, as over a lamp or gas. The fingers may be wet while handling it. Its use in submarine cables and other electrical apparatus is very extensive. *W. P. Bolles.*

GYNÆCOLOGICAL EXAMINATIONS.—History.—A proper history is a necessary preface to the diagnosis of every gynæcological case. It should not of necessity be lengthy, but certain facts in the life history of the patient, peculiar to her sex, which may have an especial bearing upon the condition of the female organs, should be carefully inquired into.

We will pass over the points common to all histories and simply emphasize those having a gynæcological bearing. The menstrual history should be thoroughly ascertained. The age at which the menses first appeared; the duration of the flow; the quantity and character; if accompanied by pain, whether it develops before, during, or after the flow; the regularity of the periods; and, finally, the history of the menopause—these are all subjects for inquiry.

In judging the condition of the menstruation as to duration, quantity, and regularity, it is well to remember that in this respect every woman is a law unto herself, and she must therefore be judged according to her own standard. But, her habit in this respect having once been established, she should not deviate from it.

The history of her pregnancies should be thoroughly investigated, as about two-thirds of all patients coming to the gynæcologist can trace their sufferings from a miscarriage, a difficult labor, or an abnormal puerperium.

Pain in some form or other is the most prominent gynæcological symptom, and is usually responsible for the patient's seeking the aid of her physician. The pain may be in the form of headache, backache, pelvic tenesmus, or a sensation of bearing down; or it may be referred to some particular part of the pelvis. Its character and location should be carefully ascertained. The condition of the bowels is a very important point for inquiry, as so many of the troubles in this class of patients are due to pelvic congestion induced by chronic constipation and irregular habits of going to stool.

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* The following are mentioned in the Pharmacographia: *D. turbinatus* Gaertn., *D. incanus* Roxburgh, *D. alatus* Rox., *D. zeylanicus* Thw., *D. hispidus* Thw., *D. crispalatus*, and several others.

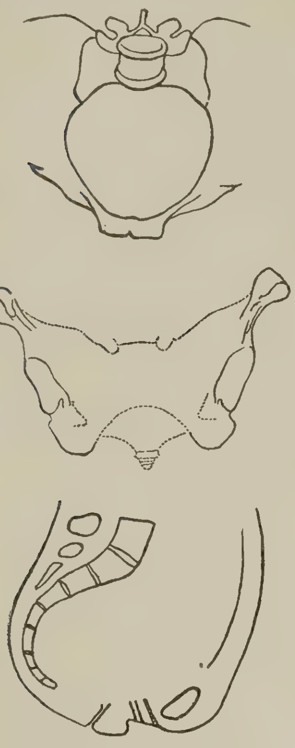

Fig. 2417.—Outline Diagrams for Recording Displacements, Growths, etc., in History-Taking.

Any bladder symptoms should be noted, especially burning or pain on micturition and frequency of the act, as they may be an indication of gonorrhœa, a disease which is now recognized as one of the most potent factors in the etiology of gynæcological cases.

The character, quantity, etc., of any discharge should be determined.

Finally, the presence of those symptoms known as neuroses, of a reflex character, should be recognized.

For the details of more extended history-taking the reader is referred to such works as those of Kelly, Reed, and Montgomery, the "American Text-Book of Gynæcology," etc. For ready reference, speed, and accuracy, we believe that the card-catalogue system, used in conjunction with outline diagrams of the various pelvic planes, in which it is possible graphically to note the size, situation, and shape of growths, displacements, etc., is of especial value in recording gynæcological cases. Rubber stamps of diagrams of the pelvis and abdomen have been devised by Dr. R. L. Dickinson, of Brooklyn, and their utility is testified to by many eminent gynæcologists (see Fig. 2417). Whatever system of history-taking is adopted it should be strictly adhered to, as routine habits will undoubtedly guard against error.

The novice will do well to remember, if he wishes to avoid embarrassment both to himself and to his patient, that all subjects of a delicate nature should be approached in an open, frank manner, devoid of subterfuge or insinuations of any kind, and coupled with the kindness and dignity of manner befitting a gentleman.

That the patient will submit to an examination should be taken as a matter of course, as at the present day most women know that such a procedure is a necessity and are prepared accordingly.

Anæsthesia.—In virgins it is desirable when possible to examine under anæsthesia, for as a rule, a first examination of such patients is very unsatisfactory, and therefore productive of no positive diagnosis. Nitrous oxide is an ideal anæsthetic for such a case.

If it is possible to avoid it, a vaginal examination should not be made in *virgines intactæ*. In the majority of cases a rectal examination will answer all purposes. The method of recto-abdominal palpation to be used will be described later.

Not infrequently in married women, if there happens to be an unusual rigidity of the abdominal muscles or a superabundance of fat, it is desirable to employ an anæsthetic, especially when the advisability of an operation is dependent upon an accurate diagnosis. When an examination is decided upon it should always be carried out in a thorough manner, and this necessitates that a systematic plan of procedure should be followed.

Nurse.—Whenever possible, a third party should be present, not only for the comfort of the patient, but as a protection to the physician from the malicious charges which the records show are by no means uncommon. If the physician can have a nurse at his disposal, this plan is by far the best, as the ready assistance and soothing influence of a trained female assistant go far toward rendering the ordeal less trying to the patient, and enable the physician to conduct his examination with much greater facility. When a nurse is not available, a female friend brought with the patient may often be of great assistance in holding a speculum, etc., but there will be many occasions when the general practitioner will have to conduct his examination unaided. While an assistant is certainly desirable, she is by no means indispensable.

Table.—The question as to what is the best table for gynæcological examinations is one that is often asked by the novice. The simpler the table the better. A costly complicated table or chair is not at all necessary, and a great many gynæcologists work with one of the simplest construction. An ordinary solid table, four feet long, two feet wide, and two and one-half to three feet high, will answer for all ordinary purposes. The foot of the table should be raised about two inches, and should be fitted with foot-rests. An extension arm or leaf attached to the right-hand corner is of great utility when employing Sims' position, as it allows the legs and feet of the patient to have a proper support, when the buttocks are drawn to the edge of the table.

A valuable adjunct, in the writer's opinion, is a pair of Edebohls' leg-holders.* They consist of two perpendicular rods that are attached to the corners of the table and have slings at their upper ends. The feet being fastened in the slings, are elevated to such an extent that the thighs are flexed upon the abdomen and rotated outward. This insures the greatest amount of relaxation of the abdominal muscles, and successfully prevents the approximation of the patient's knees. It is therefore of especial value in nervous patients.

Placing the Patient upon the Table.—If a nurse is not available, the physician should understand how properly to place the patient upon the table, so that he may not appear awkward or render the ordeal unnecessarily embarrassing. A screen should always be at hand, behind which the patient is instructed to retire in order to loosen all tight clothing about her waist, and especially to unfasten her corsets.

In all cases the patient should empty her bladder before going on the table. This is a detail that is frequently neglected, and it is the cause of an unsatisfactory examination in many instances. It is likewise of advantage that the lower bowel should be emptied, and when possible the patient should be instructed to take an enema before coming to the physician's office. The patient should be first placed in the dorsal position to permit of the bimanual examination. A stool or chair is placed at the foot of the table and the patient is directed to stand upon it, while the physician holds up a sheet between the patient and himself. She is then instructed to lift up all her skirts behind and sit down upon the edge of the table. She next lies down and the sheet is thrown over her, while her feet are adjusted in the foot-rests. The folds of the sheet are then wrapped about each leg so that there is no part exposed but the vulva.

The Examination.—The examination for purposes of diagnosis should consist of two parts—the first without instruments, and the second with instruments. It may be possible to arrive at a diagnosis by the bimanual touch alone, but an examination confined to this procedure alone cannot be considered thorough or complete; an actual inspection of the cervix, and an exploration of the uterine cavity are in many cases indispensable if an accurate opinion is to be given as to the conditions present.

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* New York Jour. of Gyn. and Obstet., January, 1893.

The Examination without Instruments.—This should be conducted systematically. A good plan is to investigate the parts from without inward, commencing with the external genitals; then the vagina, cervix, uterus, ligaments, and the appendages are examined in order.

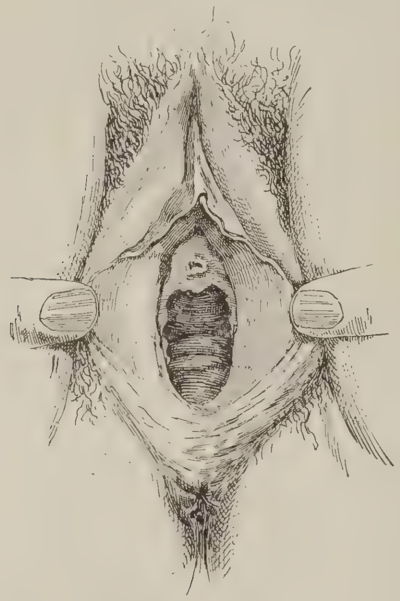

FIG. 2418.—Method of Separating the Labia for Inspection of External Genitals.

The Inspection.—This is an extremely important part of the examination, and it is too frequently omitted.

The labia majora are separated with the fingers of both hands, and the hood of the clitoris is retracted, so as to reveal any adhesions or retained concretions which may be the cause of irritation sufficient to produce neurotic disturbances. The meatus urinarius is examined for caruncle, prolapse of urethral mucous membrane, or urethritis. Skene's glands are to be observed for evidences of inflammation and discharge. These glands are very often the site of a latent gonorrhœa which would be overlooked unless they were carefully examined. The presence of a discharge in the urethra or from Skene's glands can best be determined by "milking" the anterior vaginal wall with the palmar surface of the index finger. A suspicious discharge should be stained for gonoccocci.

Prolapsus of the anterior and posterior vaginal walls (cystocele and rectocele) and procidentia uteri should be looked for, and so also should varicose veins of the vulva which are the result of some obstruction to the circulation and may be indicative of a tumor or growth blocking the pelvis.

The amount of prolapsus can be best judged by getting the patient to strain or bear down as if at stool, while the examiner's fingers separate the labia. This method shows the degree of relaxation of the vulvar outlet and the amount of supporting power of the pelvic-floor muscles. Injuries to the levator fibres and the pelvic fascia are thus accentuated. The degree of laceration of the perineum should never be estimated by a superficial inspection, as there may be an ample cutaneous covering, but with no body back of it. If the body of the perineum be grasped between the thumb and forefinger, after the latter has first been introduced into the rectum, the amount of muscular structure can be readily determined.

Bartholin's glands should always be examined for evidences of inflammation, which is almost invariably gonorrhœal in character. Latent gonorrhœa will be discovered by the careful examiner in the vicinity of these glands in a surprising number of cases. Normally the mouths of the ducts, which are situated on each side of the labia majora just below the centre, and usually behind a tag or ear of the remains of the hymen, are of the same color as the surrounding mucous membrane. The normal secretion which can be expressed from them is a glairy, colorless fluid like white of egg. Whenever the mouths of the glands seem to be much darker in color and to be eroded, suspicion should at once be aroused. If gonorrhœa is still present, the secretion expressed from the glands will be found to be turbid or purulent, and, if careful search is made, gonoccocci will usually be found. In such a case the gland itself can be felt between the thumb and finger to be decidedly enlarged and sometimes tender.

The anus and rectum should be searched for hemorrhoids, fissure, fistula, etc. The rectal mucous membrane can be readily everted by the finger placed within the vagina.

Any inflammatory condition of the vulvo-vaginal mucous membrane, if associated with copious purulent discharge, can hardly escape the notice of the careful observer, who will recognize it as a specific infection. Likewise the presence of condylomata, chancroids, venereal warts, etc., will readily be detected. It should always be borne in mind that an innocent wife is frequently a sufferer from diseases of this class through no fault of her own, and in utter ignorance of their nature.

The Bimanual Touch.—After completing the inspection, the physician will next lubricate the examining fingers with some lubricant, as vaseline, glycerin, or lubrichondrin. (The advantage of the latter is, that it is readily soluble in water, so that the hands can be speedily cleansed after they have been smeared with it.)

The examiner should accustom himself to the use of the fingers of either hand in the vagina, as it is easier to reach the left appendage with the left hand, and the right appendage with the right hand.

At first it is best to use the index finger alone in the vagina, but later, if the vagina will permit, the middle finger should be used in conjunction with the index finger. In introducing the fingers, they should be first flexed and the vulvar opening approached by sweeping the knuckles of the flexed fingers over the perineum from below, until the *knuckles* slip into the vaginal orifice, then the fingers are straightened until they find their way over the perineum into the vagina. By the employment of this method it will be possible to avoid touching the clitoris, urethra, and vestibule with the tips of the fingers, and should the circumstances of the case not permit of an inspection (as in an emergency examination, with the patient in bed), the entrance to the vagina can always be found with the greatest ease and without causing any pain or distress whatever to the patient.

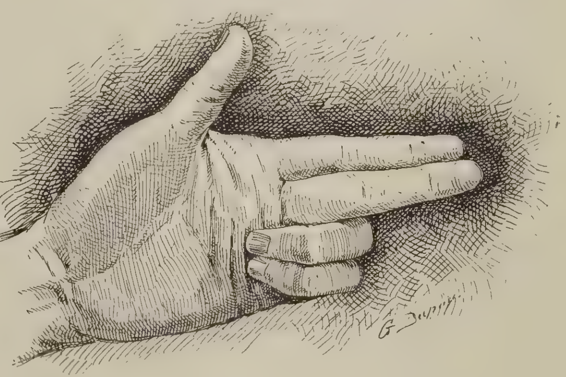

FIG. 2419.—Position of Fingers for Vaginal Examination

After the fingers have gained entrance into the vagina, the size, thickness, and sensitiveness of the organ are to be noted. The mucous membrane may present a smooth, velvety feel as when the rugæ are obliterated, or it may feel harsh and granular as in certain forms of vaginitis. Spasm of the vagina (vaginismus) may be observed as the fingers pass the introitus.

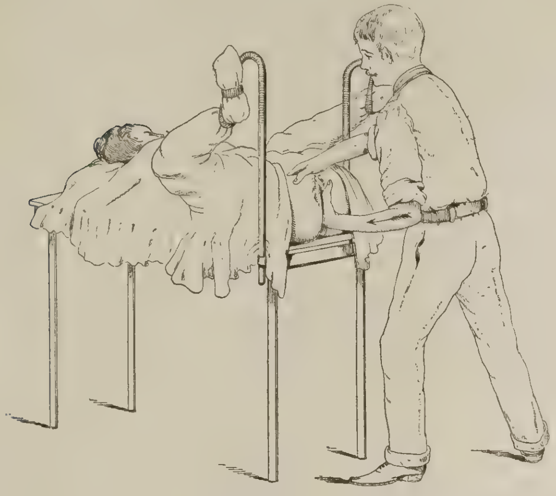

FIG. 2420.—Bimanual Examination, with the Patient on the Table.

It is important that the fingers should be held in a manner that will insure deep penetration into the pelvic cavity. The hand must be rendered as narrow as possible to permit its passage between the ischial tuberosities. When this is accomplished the whole pelvic floor can be pushed up or invaginated so as greatly to increase the penetration of the examining fingers, and thus render accessible to the touch parts which cannot otherwise be reached.

The hand should be held in a perpendicular position with the thumb extended so as to avoid the symphysis. The index and middle fingers rest in the vagina with the palmar surface of their tips inclining upward. The ring and little fingers are flexed upon the palm at the *middle* joint. It will be seen that this will give the minimum of breadth to the hand, allowing its passage between the tuberosities, while the perineum is pushed up on the knuckles of the ring and little finger (see Fig. 2419). The mistake is frequently made of flexing the fingers at their junction with the metacarpal bones. This will bring the whole length of the third phalanx of the fingers across the pelvic outlet which will render it impossible for the hand, which is then at its greatest width, to enter the pelvis. If necessary, the thumb may be closed upon the index finger so that it will pass under the pubic arch.

The elbow of the examining hand should rest against the examiner's hip, and all pressure should be made by throwing the weight of the body upon the elbow, thus allowing the muscles of the forearm and arm to be at rest, which greatly facilitates the vaginal touch (see Fig. 2420). As the fingers pass on toward the upper portion of the vagina, they should convey to the examiner a knowledge of the direction of the canal, of any abnormal relaxation of its walls, and of the presence of cysts or other abnormal growths. The presence or absence of fæcal matter in the rectum can be readily made out with the finger in the vagina. Sometimes hard scybalous masses may be mistaken for an abnormal growth by a careless observer, but they can usually be indented on pressure. However, if there is any doubt, an enema will promptly clear up the diagnosis. As soon as the cervix has been reached, the fingers should be rotated until their palmar surfaces are directed upward, and their tips should be slipped under the cervix until that organ rests upon them. The relation that the cervix bears to the axis of the vagina should be accurately noted. When the uterus is in its normal position, its axis is approximately at right angles to the axis of the vagina. Therefore the tip of the examining finger should touch the anterior wall of the cervix as it reaches the upper portion of the vagina. Should the examining finger directly enter the mouth of the cervix, it would be an indication that the uterus was displaced backward (retroverted), and that, therefore, the axis of that organ was parallel, or continuous, with the vaginal axis—unless further examination showed that the body of the uterus was flexed upon the cervix. In cases of extreme retrodisplacement, the cervix would be found to be pointing upward toward the symphysis, and the entering finger would encounter the posterior cervical wall (see Fig. 2421).

In anteversion the cervix will be found to point backward, its axis forming an acute angle with the axis of the vagina.

It must be borne in mind that the position of the uterus can be greatly influenced by the amount of urine in the bladder. A full bladder will throw the uterus into a position of retroversion. Errors will be avoided if the precaution is taken to have the bladder emptied before the examination.

The condition of the cervix itself can readily be determined by the sense of touch. The number, extent, and location of lacerations (if any are present) should be noted. It is important also to determine the degree of patulency of the os, and whether any granular erosion or carcinomatous induration exists. The presence of dense scar tissue in the angles of lacerations should be felt for, and the effort should be made to ascertain whether there is any hyperplasia of the cervix or any cystic degeneration of the Nabothian glands. Cysts of the glands of the cervix give to the touch the impression of the presence of buckshot under the mucous membrane.

The normal position of the cervix in the vagina is usually at a point corresponding to about the junction of the upper and middle thirds, and ordinarily it is not difficult to reach. In some cases, when there is a very deep vagina, or when the pelvic muscles are rigid and unyielding, it may be difficult to reach the cervix. It is a good plan to place the external hand gently upon the lower abdomen in commencing the examination; then, if the cervix cannot be readily reached, gentle pressure should be exerted in the direction of the axis of the pelvic inlet. This will depress the uterus and bring it within touch of the fingers in the vagina.

If the uterus is prolapsed, the cervix will naturally be found nearer the vulva than is normal. Care must be taken to differentiate a prolapsus of the uterus from an elongated or hypertrophied cervix.

After the examination of the cervix as above described, the next step will be to examine the uterus as a whole. The knowledge obtained by the simple vaginal touch of the cervix must be further amplified by the bimanual touch, if one wishes to arrive at a complete diagnosis of the position and condition of the uterus. It is obvious that if a flexion of the uterus exists, the position of the fundus, as indicated by the relation of the cervix to the vaginal axis, will be incorrect.

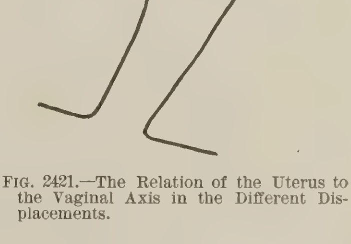

FIG. 2421.—The Relation of the Uterus to the Vaginal Axis in the Different Displacements.

In commencing the bimanual examination the physician should pass the tips of the vaginal fingers under the cervix, so that it shall rest upon their palmar surfaces. The external hand rests upon the abdomen midway between the symphysis and the umbilicus, ready to make counter-pressure from above.

The management of the external hand is a very important matter. Too vigorous pressure is the rule with the novice, and it will promptly insure failure. Such a procedure will cause the patient to resist to the utmost the rude invasion, by contracting her abdominal and pelvic muscles. It is therefore well to bear in mind, from the very beginning, that in the majority of cases more can be accomplished by gentleness of manipulation and skill, than by physical force. When it is necessary to use deep pressure, it must be done slowly and gradually, so as not to alarm the patient. By the exercise of strategy in distracting the patient's mind from the examination, as by asking questions and by getting her to take deep inspirations, we shall be able to seize the moment when the abdominal muscles are relaxed and gain the desired entrance into the pelvis with the external hand.

The four fingers of the external hand should always be kept close together, and the palmar surfaces of the fingers should be used as much as possible and not the tips. To separate the fingers and to use the tips is decidedly unpleasant to the patient, and will cause her to resist.

The first object of the bimanual examination should be to get the uterus between the two hands, so that it can be palpated. With the cervix resting upon the fingers in the vagina, slight upward pressure in the direction of the inlet of the pelvis is made, while the external hand makes gentle counter-pressure from above, gradually increasing until the fundus of the uterus is reached. This can be told by the fact that the pressure on the fundus is at once communicated to the fingers in the vagina, upon which rests the cervix (see Fig. 2422).

While holding the uterus in this manner, the size and shape of the organ can be judged, and also the amount of mobility that it possesses. The uterus should normally give the impression of being suspended between elastic ligaments. It is movable forward or backward, upward or downward, in response to moderate pressure. On the pressure being removed, the organ should promptly regain its normal position. In examining for the mobility of the uterus in this way, valuable knowledge can be gained as to the presence or absence of adhesions, or of infiltration of the vaginal vault or broad ligaments, which would cause various degrees of fixation of the uterus.

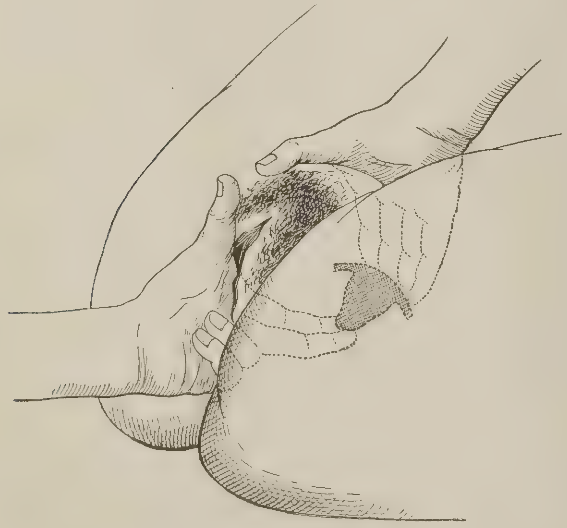

FIG. 2422.—Locating the Fundus and Cervix by the Bimanual Method.

The size of the uterus can be judged after a little practice, as one soon learns the impression that the normal uterus conveys.

Any irregularity on the surface of the fundus uteri, such as might be caused by fibroids or malignant growths, may be determined by the external hand.

The various positions that the uterus may assume must be diagnosed by comparing the relation that the cervix bears to the vaginal axis, and the position that the fundus occupies as determined by the external hand.

If the cervix is at right angles to the vagina, and the external hand discovers the fundus about midway between the umbilicus and the symphysis, the position of the uterus is normal.

Should the uterus be anteverted or anteflexed, it would be necessary to explore with the external hand right up to and behind the symphysis, until the fundus had been located. The position of the cervix would indicate whether the uterus was anteverted or anteflexed, and this could be further confirmed by slipping the vaginal fingers in front of the cervix, when with the external hand on the fundus any sulcus or bend in the organ could be easily appreciated.

Three varieties of anteflexion may be recognized. The body of the uterus may be in its normal relation with the pelvis, while the cervix is bent so as to lie in the axis of the vagina, instead of at right angles to it. This is spoken of as anteflexion of the cervix. The opposite of this condition may exist, the cervix being in its proper position, while the body is bent forward upon the cervix. This variety is designated as anteflexion of the body, in contradistinction to the above. Then again the third variety may occur, in which both cervix and body are out of their normal positions, the flexion being very acute, and the cervix and body closely approaching each other.

When the uterus is displaced or flexed backward, the search for the fundus is made toward the sacral promontory. It is apparent that if the fundus is at or below the level of the promontory, it will be found extremely difficult—unless there is unusual relaxation of the abdominal muscles, or unless we employ a general anæsthetic—to get the uterus between the hands; indeed, in some cases, it is simply impossible to accomplish this.

The fact that the fundus could not be found, and that the cervix was pointing in the axis of the vagina, would be strong presumptive evidence that there was a backward displacement of the organ beyond the sacral promontory.

Retroversion is classified by most authors into three degrees: When the fundus points toward the sacral promontory, it is a retroversion of the first degree. If it points into the hollow of the sacrum, being practically continuous with the vaginal axis, it is the second degree. When the fundus is still lower in the pelvis, and the cervix begins to point upward toward the symphysis, it is classified as the third degree. (See Fig. 2421.) In the second and third degrees of retroversion, it is often impossible to reach the fundus with the external hand by the ordinary method of examining. In such cases the difficulty may be overcome if the uterus be drawn down by a tenaculum, until the cervix is nearly at the site of the hymen. If the index finger be inserted into the rectum while the uterus is drawn down it is frequently possible to palpate the body and fundus with great facility. Kelly's corrugated tenaculum is designed especially for this purpose, as it enables the examiner firmly to hold the tenaculum with the external fingers of the lower hand, while the counter-pressure is made as usual with the upper hand on the abdomen (see Fig. 2423). This method enables the examiner to reach the fundus with both hands.

Retroflexion of the uterus can be differentiated from retroversion by the presence of a distinct sulcus or angle being felt at the junction of the cervix with the body. When a sulcus cannot be felt, and the fundus is out of reach of the finger in the posterior vaginal fornix, it is to be inferred that the uterus is not retroflexed. The afore-mentioned method of drawing down the uterus will permit this point to be accurately determined, unless adhesions prevent, in which case the diagnosis must be left until it can be settled by the uterine sound or probe.

It is wise always to confirm a diagnosis of flexion by the sound, as a subperitoneal fibroid on either the anterior or the posterior uterine wall will frequently be a cause of deception.

Lateral displacement of the uterus to the right or left of the median line should be carefully noted. A uterus in such a position has either been drawn over to one side by the contraction of adhesions, or it is pushed over by the presence of a cyst or growth filling the opposite side of the pelvis.

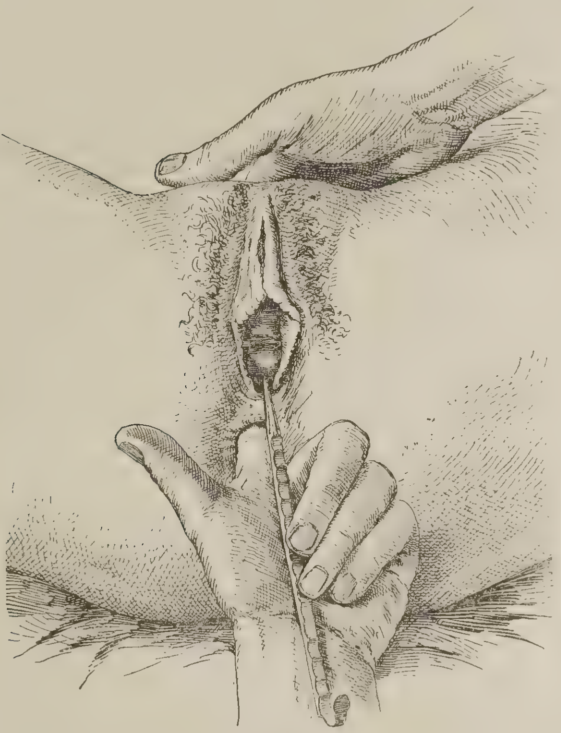

FIG. 2423.—Recto-Abdominal Palpation while Drawing Down a Retrodisplaced Uterus with Kelly's Corrugated Tenaculum.

Normally the pelvic organs, with the exception of the ovaries, are not sensitive to ordinary palpation. Deep pressure upon these organs will cause a nauseating pain, accompanied with faintness, similar to that produced by pressure upon the testicles. Tenderness of the uterus will generally indicate disease of that organ, as endometritis or metritis, although there is a certain class of patients whose organs, even when not appreciably diseased, manifest an abnormal degree of hyperæsthesia. Pelvic sensitiveness is one of the prominent symptoms of an hysterical patient.

One of the most important items of information to be derived from the examination is the consistency of the uterus and the surrounding structures, as determined by the sense of touch. Each structure has its own standard, and the examiner must first become thoroughly familiar with the normal consistency before he can appreciate deviations which indicate pathological changes. The soft, friable condition of a carcinomatous cervix, the boggy impression conveyed by a subinvoluted or œdematous uterus, the hard plaster-of-Paris-like feel of the vaginal vault in pelvic peritonitis, the fluctuating sensation of a fluid tumor or abscess, are but a few of the conditions which must depend upon a comparison with the normal for their diagnosis.

After the examination of the uterus has been completed, the attention should next be directed to the ligaments which aid in its support. These ligaments are prone to inflammatory thickening, which may give rise to pain, and which frequently interferes with the normal mobility of the organs.

The anterior, posterior, and lateral fornices of the vagina are to be palpated to ascertain the condition of the utero-vesical, utero-sacral, and broad ligaments. Normally the vaginal vault is elastic to the touch, and should induration and thickening of the ligaments be present, these conditions can usually be made out by palpation.

The vaginal fornices must be carefully explored by bimanual touch, for the presence of cysts, growths, prolapsed ovaries, collections of fluid, etc., which may occupy the cul-de-sac of Douglas or the utero-vesical space.

By comparing one lateral fornix with the other, as regards the ease with which the examining fingers may be moved in different directions, and also by comparing the two sides as regards the degree of pain elicited by pressure, one may obtain considerable information in regard to the pathological conditions that may be present.

It is not possible in a limited article like the present one to do more than hint at the diagnosis of the many complicated conditions which will be found in examinations of the vaginal fornices. It is hardly necessary to say that years of experience may be required before it is possible for one to acquire the *tactus eruditus* necessary to ascertain, by digital exploration, the pathological conditions that are present in the pelvic cavity in any given case. The most expert gynæcologists not infrequently see, on opening the abdomen, that their diagnosis was at fault. A thorough appreciation of the normal condition of the parts will enable the novice more readily to recognize pathological deviations, and especially is this true of the uterine appendages. It is a frequent occurrence, in the writer's experience, to come across men, in active general practice, who state that the palpation of the uterine appendages is a closed book to them. Diagnosis of diseases of these important organs is entirely beyond their reach for the reason that they cannot feel the adnexa, although they repeatedly examine cases in their practice. They can often make a diagnosis as to the position of the uterus, the condition of the cervix, or the pelvic floor, but the condition of the ovary and tube is like the "will-o'-the-wisp;" it easily evades the simpler methods of examination.

In examining for the ovaries and tubes, the novice will frequently attribute his failures to the shortness of his phalanges, and he will endeavor by pure physical force to gain further entrance into the pelvis, with the result that he causes needless pain to the suffering patient. As she is frightened by fears of worse pain to come, she sets to the utmost her abdominal and pelvic-floor muscles, in order to resist the rude invasion with which she is threatened, and thereby makes it impossible for the examiner to get within reach of the adnexa with his examining fingers. The novice usually has no definite plan of procedure in his mind, and his one idea as to the position of the ovary is, that it lies on one side of the uterus at or near the plane of the fundus, just as he has seen it pictured so often in his text-books.

A careful observance of the preliminaries to the examination—such as loosening the corsets and clothing, emptying the bladder, etc.—is essential to success. It is well to remember that it is easier to reach the left appendage with the left hand in the vagina, and the right appendage with the right hand.

The first step necessary to the palpation of the adnexa is to locate the fundus of the uterus, as with the fundus as a guide the location of the appendages is made easier. This is done after the manner previously described and shown in Fig. 2422. After the cervix and the fundus of the uterus have been located, the next step is to remember that the tube and ovary, unless bound down by adhesions, are *movable*, as can well be brought to the examiner's mind when he remembers how often he has seen the operator bring up the appendages out of the pelvis upon the abdomen of a patient through an abdominal incision, and how loosely they have appeared to him to be attached to the horn of the uterus.

To this fact is to be attributed the failure, in many cases, to reach these organs. The novice examines in *one* place for them, and as they are slippery bodies, they are as difficult for him to get hold of with his external and internal examining fingers, as the proverbial eel. Therefore he must endeavor to *catch* these organs, and as they may lie or be pushed into any part of the space between the middle line of the body and the lateral pelvic wall, he must systematically search each half of the pelvis.

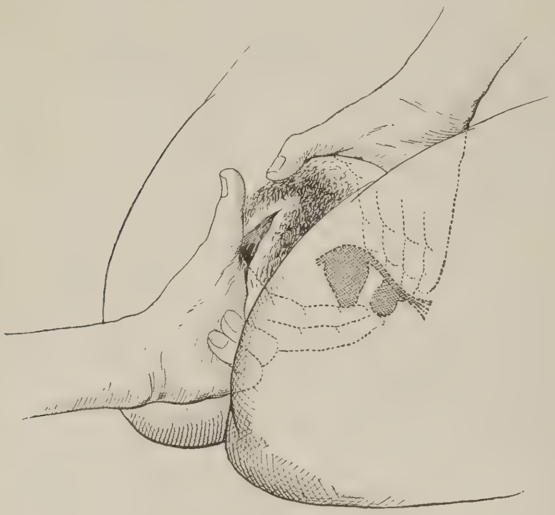

FIG. 2424.—Palpating the Adnexa by the Bimanual Method. Catching the appendage between the tips of the opposing fingers.

It is better that one hand do the searching, the other remaining stationary for the time being, to act as a counterpoint. After locating the cervix and fundus uteri, the examiner should slip the vaginal finger or fingers to one side of the cervix into the lateral fornix, and should make pressure with them in a direction upward and backward, at a point midway between the cervix and the pelvic walls. These fingers should then remain stationary, while the four fingers of the external hand, curved in the shape of a scoop, are employed in systematically exploring the area from the fundus to the side of the pelvis, in lines radiating to the examining fingers in the vagina. It may frequently be necessary to go over the ground repeatedly before the ovary can be caught. The position of the vaginal fingers is to be varied from time to time, antero-posteriorly and laterally, so as to cover new planes. As soon as the ovary and tube are imprisoned between the scoop formed by the external hand above, and the fingers in the vagina below, their character, size, sensibility, and consistency can be made out as they slip between the opposing finger tips (see Fig. 2424). The normal tube can be traced from the horn of the uterus; it feels like a cord of about the diameter of a slate pencil, and it is not painful to moderate pressure.

The normal ovary feels as large as a walnut, and when it is subjected to pressure the patient experiences the same sickening sensation and pain as does the male when his testicle is similarly pressed upon. The opposite side of the pelvis is to be explored in a similar manner for the other appendage, the right hand being used in the vagina for the right adnexa and *vice versa.*

In cases in which this method does not succeed, the examiner should resort to recto-abdominal palpation. In this method the index finger is introduced into the rectum instead of into the vagina, and the palpation is made with the opposing hand, as in the bimanual examination just described.

When the uterus is retroverted or retroflexed, recto-abdominal palpation is usually preferable, and is a great gain, especially if the uterus is drawn down to the vaginal outlet by a tenaculum or volsellum, which permits the fundus to be reached posteriorly, and brings the adnexa within the radius of the examining finger (see Fig. 2423). In commencing the practice of bimanual palpation it is wise to select a patient who has borne children, who is thin, and who has relaxed abdominal walls. In women who are fat, and who have rigid abdominal muscles, even the expert must, in many cases, necessarily resort to complete anæsthesia before he can make a positive diagnosis. The beginner must not feel discouraged if he fails satisfactorily to feel the adnexa in his first attempts, but by exercising patience and persistence, avoiding haste, paying careful attention to all the minor details, and having a definite plan of procedure in his mind, he will surely attain ultimate success.

The differential diagnosis of the various pathological conditions that may be found about the uterus is such an extensive subject that it can only be touched upon here. In general, fluid accumulations or cystic growths that can be felt through the vaginal vault are diagnosed by the sense of fluctuation and elasticity.

If a mass is diffuse, boggy, ill-defined, immovable, and tender, one would suspect an inflammatory exudate. If a mass gives evidence of fluctuation, of increased heat, and of being very painful when pressed upon, while the patient at the same time gives a history of exposure to infection, of fever, and possibly of chills, the presence of an abscess would be indicated. In inflammatory affections of the tubes and ovaries, these organs frequently are displaced into the cul-de-sac and fixed by adhesions. Generally a hydro- or pyo-salpinx is of a sausage shape, and can be traced to the uterine cornua.

Whenever the bimanual examination discovers the presence of a large growth, or it is self-evident that the patient has an enlargement of the abdomen, abdominal palpation must be practised. Special works will have to be consulted for the details of the technique necessary. Gentleness of touch is here as essential to success as in the vaginal examination. The novice will do well to avoid giving a positive opinion as to the nature of an abdominal enlargement. Pregnancy, ascites, fat, gas, fæcal accumulations, a distended bladder, are but a few of the conditions that must be differentiated from tumors.

When the presence of a growth is certain, not only its character, but also its relations to the pelvic organs, must be carefully studied. The presence of adhesions is judged by the amount of fixation that exists. It is a good plan to examine all abdominal enlargements in various postures. Percussion is of value in mapping out the relations of the intestines.

It should be borne in mind that in acute inflammatory affections of the pelvic contents, appendicitis and ectopic gestation should be carefully differentiated. Likewise, at the present time, a gynæcological examination can scarcely be considered complete without an investigation of the mobility of the kidneys.

Examination with Instruments.—After the bimanual examination has been completed, the instrumental examination is in order.

The instruments necessary are few, and comprise a Sims speculum, a bivalve speculum, a depressor, dressing forceps, single tenaculum, double tenaculum or bullet forceps, probe, sound, and a small flexible spoon curette. Cystoscopic tubes, a urethral endoscope, and an aspirating syringe would render the armamentarium complete. Suitable basins for cleansing solutions, etc., should be at hand, and also an abundance of absorbent cotton. The absorbent cotton should be made into cotton balls, as they are convenient and greatly facilitate the cleansing of the vulva, vagina, etc.

The Speculum.—Of all the many varieties of specula that have been devised, there is none better than the original Sims instrument, a description of which can scarcely be necessary. The bivalve or trivalve specula are but substitutes for the Sims and should be resorted to only from necessity and not from choice. When an attendant or nurse is not available, the examiner may have no option but to use the bivalve speculum; otherwise, the Sims should be used, because by no other method can such a satisfactory examination of the vagina and the uterus be made.

The Sims speculum alone does only a small part of the exposing of the vagina. It is in the Sims posture that the great virtue of this method lies. In the correct Sims position, the pelvis is tilted over at an angle of forty-five degrees, so that the intestines, etc., gravitate out of the pelvic brim, as if out of a basin. This produces a vacuum in the pelvis, and when the speculum retracts the perineum and opens the labia, the air rushes in and balloons the vagina, so that its folds are obliterated, permitting an unobstructed view of the vaginal vault and the cervix. In this position the uterus, unless fixed, can be drawn down nearly to the orifice of the vagina, so that treatment or examination is greatly facilitated.

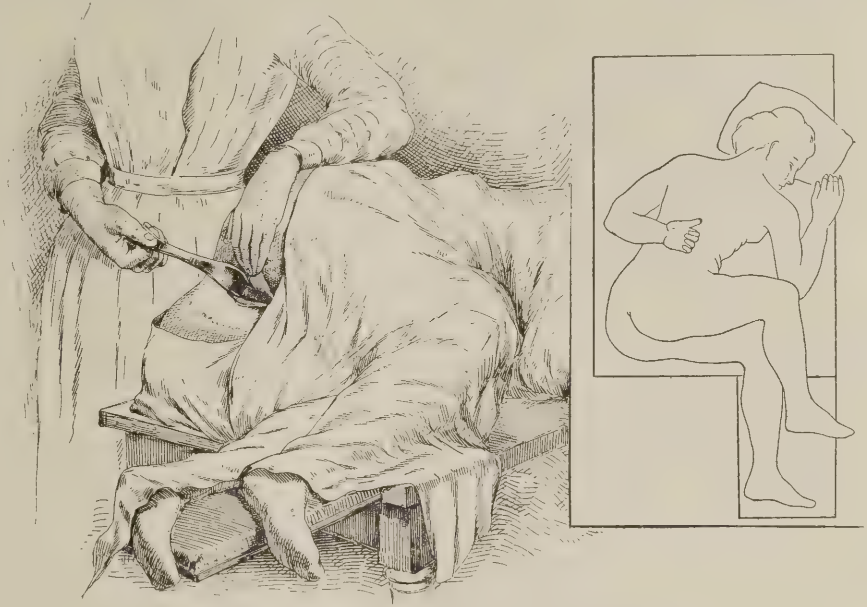

FIG. 2426.—Correct Posture of Patient and Nurse in the Sims Position.

The bivalve speculum gives but a limited view of the cervix, and affords only a small amount of space in which instrumental manipulations can be carried out. Furthermore, if the uterus is in the normal or in an anteverted position it is sometimes extremely difficult, through this pattern of speculum, to pass a sound or to make intrauterine applications.

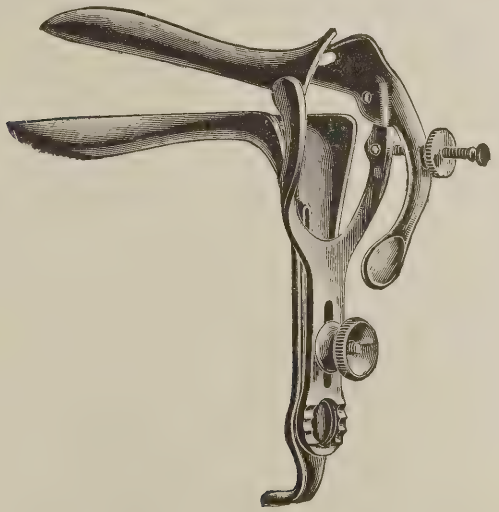

FIG. 2425.—Graves' Bivalve Vaginal Speculum.

A good example of a bivalve speculum is that of Graves (Fig. 2425). It has the advantage of being adjustable at the vaginal orifice, and it can be converted into a Sims speculum. In selecting a bivalve speculum, care should be taken to see that the anterior blade is from a half an inch to an inch shorter than the posterior blade.

Various self-retaining Sims specula have been devised, and while none of them is as good as the instrument held by an assistant, the examiner will be able to get along fairly well with one of these instruments. Perhaps one of the simplest and best is Cleveland's. Ehrich's modification is also very serviceable.

The first requisite to a successful examination with the Sims speculum is a proper Sims posture. The nurse, or the physician, will direct the patient to sit up on the table and then to lie on her left side with the left arm flexed behind her back. Both knees are then to be drawn up in the direction of the chin, the uppermost knee lying above the under one. In this position the sole of the right foot will lie above the left ankle. The left hand of the nurse should then be passed under the lower buttock until the crest of the ilium can be grasped. Traction should then be made on the crest of the ilium until the lower buttock shall have been drawn to the edge of the table, while at the same time the right hand pushes the upper buttock in the opposite direction. This manœuvre will tilt the pelvis so that the brim will lie at an angle of about forty-five degrees with the table. To prove that the pelvis is properly tilted, all that is necessary is to hold a straight rod at right angles to the table and against the lower buttock, when it will be seen that the upper buttock is four or five inches beyond its neighbor. If the clothing has been previously loosened about the lower abdomen and waist, the intestines will gravitate out of the pelvis. The legs and feet should lie on an extension leaf at the right-hand corner of the table. Finally, the patient is covered with a sheet so that only the vulva is exposed (see Fig. 2426).

The physician sits at the foot of the table, and at his right hand there should be a stand upon which the instruments, basins, etc., are arranged within convenient reach. A warm carbolized solution should be used for immersing the instruments. Care should be taken to warm them properly before they are used. The nurse stands on the physician's left, facing him and close to the side of the table. With her left hand the nurse raises the upper buttock and labium, keeping her fingers separated and extended, and taking care not to use the tips at all, but to roll up the buttock with the palmar surfaces of the fingers only. If the points of the fingers are used like a claw, it is decidedly unpleasant to the patient. The physician draws down the lower buttock and labium with his left hand in a precisely similar manner, while he grasps one end of the speculum with his right hand, being careful to have the index finger project beyond the bill of the speculum for an inch or more (see Fig. 2427). The speculum and finger should have previously been well lubricated. The idea of the projecting finger is, that it is to enter the vagina in advance of the speculum as a pilot, so as to guide the tip of the instrument behind the cervix.

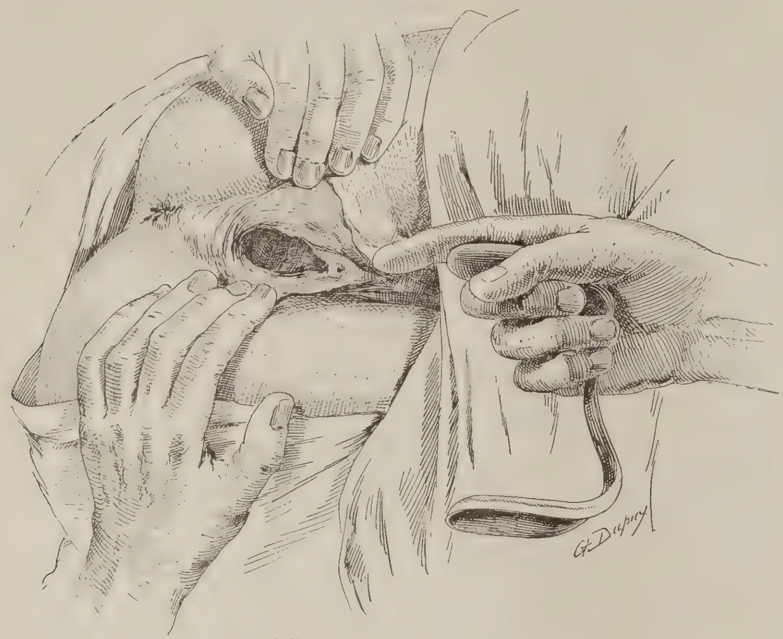

FIG. 2427.—Introducing Sims' Speculum.

The direction of the vagina must be borne in mind. As the patient lies in this position, the vagina will run in a direction toward the centre of the sacrum. As the finger enters the vagina, the speculum follows after, entering laterally; that is, the flat of the blade corresponds to the direction of the cleft between the labia. As soon as the index finger feels the cervix, the speculum can be easily guided behind it into the posterior vaginal fornix. The speculum is then rotated to its final position so that it will retract the perineum. The external end of the instrument is given to the nurse, who should grasp it firmly, the fingers surrounding the external blade while the thumb lies in the groove.

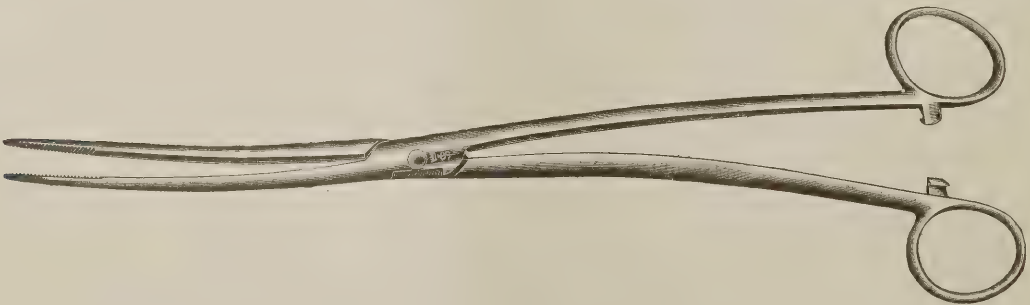

FIG. 2429.—Bozeman's Uterine Dressing Forceps.

The nurse's duties are to hold the speculum exactly as it is given her, and to keep the upper buttock retracted. She can best do this with comfort to herself and satisfaction to the examiner, if she stands straight up, facing slightly away from the physician, so that the arm holding the speculum is wrapped about her body. Her arm is thus steadied, and there is no occasion for any strain on the muscles of the hand or forearm (see Fig. 2426). If she is directed to increase the traction on the instrument, she simply rotates her whole body and does not bring into play the muscles of her arm. By this method a nurse can hold a speculum for a long period without becoming tired, and it is far more satisfactory than stooping over the patient, grasping the speculum by the shank, and keeping up all the tension with the arm muscles which soon tire and cause unsteadiness.

The Depressor.—As the perineum is retracted and the vaginal walls are exposed to view, the cervix will usually be hidden behind the anterior wall of the vagina, which bulges somewhat in front of it. We should therefore next use an instrument called a depressor, to depress the anterior vaginal wall. The depressor is practically a spatula or spoon (see Fig. 2428), which should be held between the thumb and fingers of the left hand and gently used to push aside the bulging anterior wall so that the cervix may be brought into view. Care should be taken while using this instrument that the wrist of the hand is dropped below the line of vision.

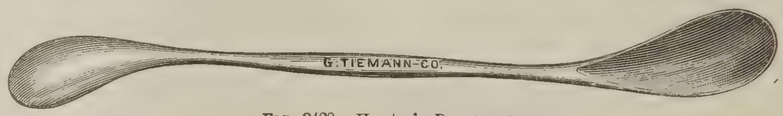

FIG. 2428.—Hunter's Depressor.

The Dressing Forceps.—As soon as the cervix is brought into view a dressing forceps, holding a cotton ball, is used to cleanse the cervix and vagina of any secretion that may be present, after which a cotton ball saturated with carbolic or other solution is used to bathe the parts. Of the different forms of dressing forceps there is a sufficient variety to suit the taste of the examiner. One having a curve is of advantage as it enables the right hand to keep out of the line of vision. Bozeman's forceps is a good illustration of this instrument (see Fig. 2429).

By the inspection of the cervix and the vagina, we are enabled to verify the diagnosis made by vaginal touch. The condition of the vaginal mucous membrane, the presence of fistulæ or of cicatrices, the extent of cervical lacerations, hyperplasia of the cervix, and erosions are all brought into view.

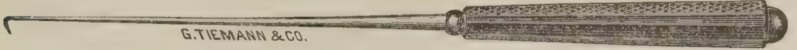

FIG. 2430.—Tenaculum.

The Tenaculum.—The next step is to seize the cervix by the anterior lip, so that it may be drawn down for closer inspection and also for the purpose of steadying the organ while a sound or other instrument is being passed into the uterus. The single-hook tenaculum, as shown in Fig. 2430, is the style of instrument usually employed. It should be hooked into the cervix through the os.

For the purposes of examination and of making intra-uterine applications, the double tenaculum has many advantages over the single instrument.

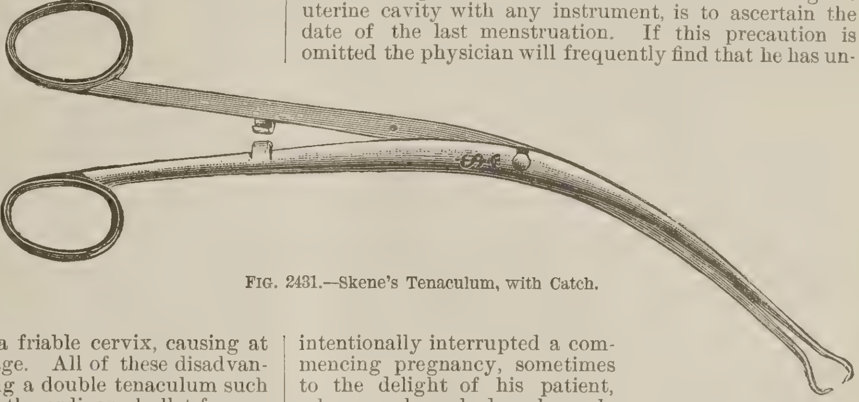

FIG. 2431.—Skene's Tenaculum, with Catch.

No matter how expert the examiner may be, he cannot help making a number of punctures with the single instrument during the course of his examination and treatment. The instrument cannot be left on the cervix, but must be held by one hand, so that if both hands are needed during the preparation of an applicator, etc., the instrument must be removed and then afterward reapplied. It frequently tears through a friable cervix, causing at times a bothersome hemorrhage. All of these disadvantages can be avoided by using a double tenaculum such as Skene's (see Fig. 2431), or the ordinary bullet forceps will answer. With the double tenaculum two punctures only are made in the anterior lip of the cervix, instead of half a dozen. The instrument is clamped on by means of the catch, so that no hand is required to hold it. It will of itself act as a depressor to keep back the bulging anterior wall. So long as it remains fastened to the cervix, the uterus will be under perfect control. A retroverted uterus can be replaced with great ease with this instrument. This is accomplished by drawing on the cervix and making it describe a circle backward into the posterior fornix. It is of course to be understood that ordinary care will be exercised, and that the instrument is at all times to be used with the same gentleness and delicacy as the single tenaculum. Great care should be used in drawing down the cervix, as this is a procedure that may do much harm and cause considerable pain, if adhesions or inflammatory conditions exist. The bimanual examination should have previously disclosed any condition of immobility of the organ, or any lack of elasticity of the ligaments. Unless the uterus can be drawn down easily without force, the procedure should not be attempted.

The Probe and the Sound.—After the cervix and its surroundings have been inspected, the next procedure will be to examine the cavity of the uterus by means of the probe or the sound.

The probe is a very flexible piece of copper or silver wire, with an olive-shaped tip, and is designed to bend on meeting the slightest obstruction. It is therefore a safe instrument with which to make an exploration of the uterine cavity (see Fig. 2432).

The sound is of a larger diameter, and is much stiffer than the probe, but is capable of being bent into any shape that may be required. Simpson's sound is the instrument usually employed (see Fig. 2433). It has a bulbous tip and at a point two and a half inches from the end there is an enlargement which denotes the normal length of the uterine canal. The shaft is marked in inches for purposes of measurement.

The sound is an instrument capable of inflicting much damage, and requires great care in its use. Great harm may be done by employing it recklessly and unskilfully. The novice had better by far use the probe only, for his investigations, until he has acquired a sufficient knowledge of the technique, and some skill in his manipulations.

The probe will reveal nearly as much as the sound, and there is no especial advantage, in the majority of instances, in employing the more dangerous instrument.

The first precaution to be taken before invading the uterine cavity with any instrument, is to ascertain the date of the last menstruation. If this precaution is omitted the physician will frequently find that he has unintentionally interrupted a commencing pregnancy, sometimes to the delight of his patient, who may have had such an object in view in requesting an examination for other trouble. The technique of using the sound is practically the same as that for introducing the probe.

The instrument should never be introduced without having the cervix clearly in view, so that it may be passed directly into the canal of the cervix without coming in contact with the surrounding parts. The method of introducing the instrument by sense of touch should be condemned just as strongly as the old method of catheterizing a patient, when it was considered desirable for the physician to be able to introduce a catheter into the bladder under a sheet.

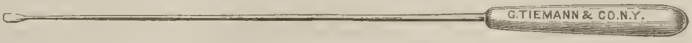

FIG. 2432.—Uterine Probe.

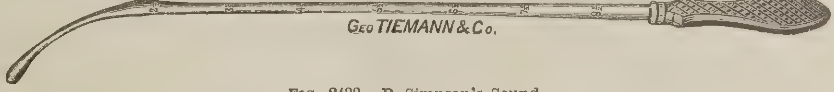

FIG. 2433.—R. Simpson's Sound.

Any instrument that is to enter the uterus in the course of an examination should be sterilized as if for an operation. Boiling is perhaps the safest plan, but when the conveniences are not at hand, the instrument can be immersed in ninety-five-per-cent. carbolic acid for a few moments, and then in alcohol to neutralize the acid. The bimanual examination will have given the physician a fairly accurate idea as to the shape of the uterus, and he should shape his probe or sound accordingly. The instrument is to be held lightly between the thumb and forefinger and the cervix steadied by the tenaculum. The tip is then passed into the external os and allowed to find its way along the canal. It will frequently become obstructed at the internal os by a shoulder or pocket in the mucous membrane, in which case a gentle twisting motion or withdrawal will enable the sound to pass the obstacle. The probe will pass a constriction at the internal os, while the sound may be arrested. Sometimes, in anteflexion, the constriction may be spasmodic in character; if such is the case, the stricture will relax if the sound is held firmly against it for a few moments. When the instrument reaches the fundus, the forefinger is slid along the shaft until it comes in contact with the cervix. The probe or sound is then withdrawn and the depth of the uterine canal can readily be noted.

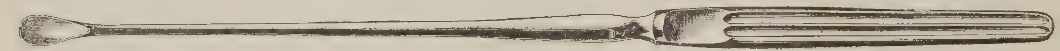

FIG. 2434.—Skene's Curette.

The sound should not be used to determine the mobility of the uterus. It is such a powerful lever that the uterine mucosa will be unnecessarily injured even if worse damage is not done. The degree of mobility of the uterus can be determined better and more safely by the bimanual examination. In the healthy uterus the sound, if skilfully passed, should not cause either pain or hemorrhage. The occurrence of one or both of these symptoms denotes a diseased condition of the endometrium. The patency of the external and internal os, irregularities on the uterine mucosa, and the presence of growths in the canal are ascertained by means of the sound. The sense of touch, as communicated through the sound, is here brought into play, and this necessitates that the instrument must be held very lightly between the thumb and fingers in order to appreciate any delicate variation.

The use of the sound as a repositor is to be condemned. Any evidence of acute inflammation of the uterus or its appendages prohibits any intra-uterine manipulations.

The Curette.—The curette is a valuable instrument for diagnostic purposes. The curette for this purpose should be small, so as to pass the internal os without difficulty. It should be dull and very flexible, so that no damage can be done with it. The spoon-shaped curette, as shown in Fig. 2434, is especially adapted for diagnosis, although a dull wire curette may be used. The spoon curette enables one to scrape off shreds of tissue and epithelium from the endometrium, which should be examined under water to disclose their gross appearance, while they are to be submitted to microscopic examination for more accurate diagnosis. All that has been said in regard to employing the sound applies equally to the curette. The instrument must be properly sterilized, and given the shape of the canal which has been accurately ascertained by means of the sound or probe. It is to be used with all gentleness. The curette is not to be used in the office to curette the uterus as for an operation; it should serve simply as a means of procuring a small amount of tissue or débris from the uterine canal for diagnosis only.

Dilatation of the Cervix.—This is a procedure which is sometimes necessary in order to admit the passage of the examiner's finger into the uterine canal for purposes of diagnosis. As it is of such a nature as to require an anæsthetic for its proper performance, as well as the usual preparations for a surgical operation, its description does not belong in this article.

Examination of the Urethra and Bladder.—This subject is fully treated in Volume II. of this work.

The Aspirating Syringe.—The ordinary aspirating syringe used in exploring the chest for pleuritic effusions is all that is necessary. It is desirable to have a long curved needle, as the curve greatly facilitates its introduction through the vaginal vault. Cystic or inflammatory masses which are situated low down in the pelvis, and which can be palpated by the examining finger through the vaginal vault, can be safely punctured with the needle and the contents withdrawn by the syringe for examination.

The Microscope.—The aid of the microscope for differential diagnosis is of especial value in gynæcological examinations. The recognition of the gonococcus by the microscope is of prime importance in investigating the character of vaginal or other discharges. In fact it is impossible to be sure of the character of a discharge without its aid. As the important position that the gonococcus holds as an etiological factor in diseases of women becomes better known, the necessity for the use of the microscope by the gynæcologist appears in a clearer light. Commencing epithelioma and carcinoma are to be detected with positiveness only by submitting uterine scrapings or small pieces of cervical tissue to microscopical examination. It must also be resorted to, in many cases, in differentiating malignant from non-malignant growths.

George Gray Ward, Jr.

HÆMATEMESIS. See *Stomach, Diseases of.*

HÆMATIDROSIS is a functional disturbance of the sweat apparatus whereby blood, through diapedesis into the coils and ducts from their surrounding vascular plexus, becomes mingled with the sweat and appears with it upon the normal skin, producing the phenomenon of so-called "*bloody sweat.*" It is an exceedingly rare occurrence, and when observed the subject has been generally a highly neurotic person undergoing some strong emotional disturbance. In some instances it has seemed to be a form of vicarious menstruation. It has been observed in the newborn. The points where it has been observed to occur are the face, ears, umbilicus, feet and hands in limited areas, giving rise to the term "bleeding stigmata" and other names. Treatment is that of the patient.

Charles Townshend Dade.

HÆMATOCELE, RETRO-UTERINE OR PELVIC. See *Extra-Uterine Pregnancy.*

HÆMOGALLOL, HÆMOL.—Two patented compounds prepared from the coloring matter in the blood and thought to be more readily absorbed than other preparations of iron. The first is obtained by the action of pyrogallol, the latter by the action of zinc dust.

Hæmogallol is a brownish-red powder, very soluble in water. The dose is from gr. v. to x. three times a day. Hæmol is a black powder, also very soluble and administered in the same dose. They have been recommended for the treatment of chlorosis and anæmia.

Beaumont Small.

HÆMOLYMPH GLANDS. (HISTOLOGY AND PATHOLOGY.)—The hæmolymph glands are lymphadenoid structures occupying a position intermediate between the spleen and ordinary lymphatic glands. In structure they closely resemble the latter, the essential difference between the two being that they possess blood sinuses in place of lymph sinuses. Transition forms between the two, however, exist; a gland may contain both lymph and blood sinuses; but the presence of the latter, however small, is sufficient warrant for its classification as a hæmolymph gland. There are also transition forms between the hæmolymph glands and spleen, many of the former, particularly in the lower animals, possessing a spleen-like pulp. The spleen itself may be regarded as a hæmolymph gland; and undoubtedly many of the so-called accessory spleens fall into the class of hæmolymph glands.

OCCURRENCE.—The existence of hæmolymph glands was first noticed in the lower animals, particularly those used for food purposes. In the steer, pig, and sheep these structures are very numerous in the prevertebral fat, and conspicuous because of their deep blood color. From their number and size in these animals it is reasonable to suppose that their function is of importance. Butchers and meat dealers have long been acquainted with their gross appearances, but have usually regarded them as blood clots. From the scientific side they have been strangely neglected, though as early as 1857 Leydig pointed out the close resemblance between these glands and the spleen. More recently they have become objects of scientific investigation, and have been found to be present also in the goat, horse, dog, rat, guinea-pig, common fowl, and turkey.

Their presence in man has only lately become a matter of careful study, though lymph glands with blood-containing sinuses have been many times observed. Such findings were, however, interpreted as ordinary lymph glands into whose lymph sinuses there had been a hemorrhage or backward flow of blood. H. Gibbes, in 1884, was the first observer to consider such glands to be permanent and independent structures. A similar view was taken by Robertson in 1890, and to this observer we owe the designation hæmolymph gland, this name having been suggested to him by Dr. Russell. The constant presence of these glands in the human body was confirmed later by Gibbes and Vincent, and more recently by the present writer. According to the investigations of the latter, lymph glands containing blood sinuses are found constantly in the human body, at all ages, and in both normal and pathological individuals. That these glands are organs *sui generis* and not hemorrhagic lymphatic glands is evident from the following facts:

First. Lymph glands containing blood sinuses are constantly present in the human body in all conditions and at all ages.

Second. The structure of such glands differs in many respects from that of ordinary lymphatic glands; and the appearance presented by hemorrhagic lymphatic glands is wholly unlike that of a hæmolymph gland.

Third. These glands in the human body show many points of similarity to the hæmolymph glands found in the steer and sheep, and the latter from their number, size, constant occurrence, and individual structure must be regarded as organs *sui generis* without question.

LOCATION.—In the lower animals the hæmolymph glands are found chiefly in the prevertebral fat, along the course of the aorta, renal and adrenal vessels, brim of the pelvis, and in the root of the mesentery. They rarely extend far out into the latter, but are occasionally found in the omentum and epiploica. They are also of rare occurrence in the mediastinal region. In man they are found in greatest numbers in the prevertebral, retroperitoneal, and cervical regions, in the neighborhood of the adrenal vessels, along the brim of the pelvis, in the root of the mesentery, but rarely extending far out into it, and are of very rare occurrence in the epiploica and omentum. They are also rare in the mediastinal tissues and along the thoracic aorta, except under conditions in which there is a general enlargement of all the hæmolymph glands of the body, as in certain forms of anæmia and leukæmia. This fact suggests the possibility of new formation of these structures in these diseases or their existence as resting glands too small to be found under normal conditions.

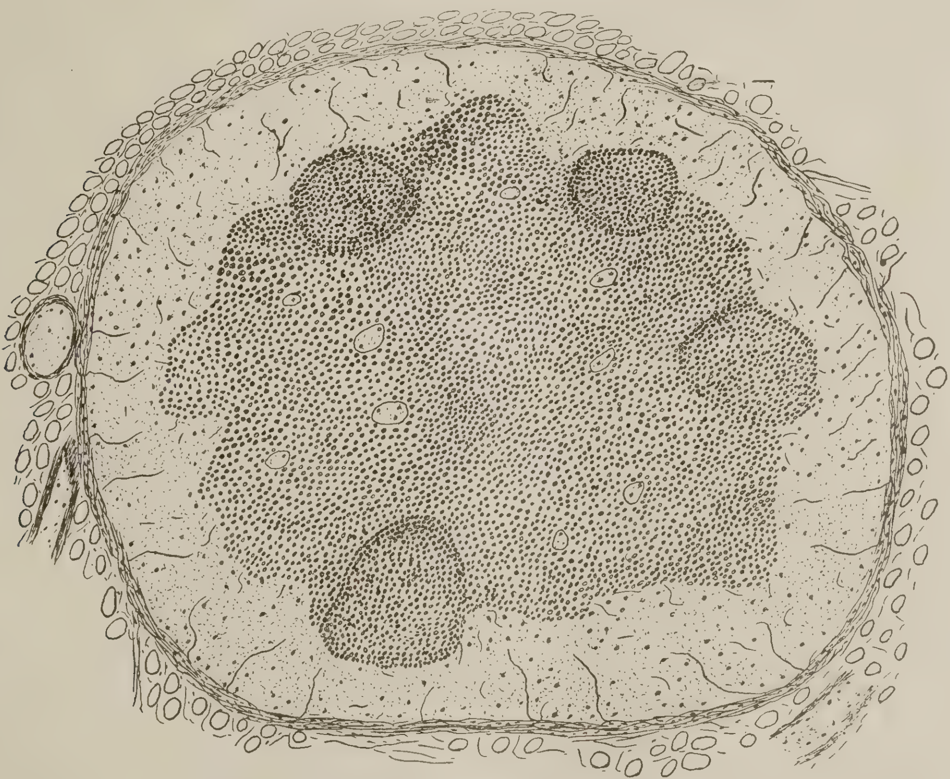

FIG. 2435.—Common Type of Hæmolymph Gland from Steer. Peripheral blood-sinus. Camera lucida drawing. Leitz objective 3; eyepiece No. II. Reduced one-third.

HISTOLOGY.—*Bullock.*—Hæmolymph glands are found in the prevertebral fat of this animal to the number of several hundred. Their deep red color contrasted with the white fat in which they lie embedded makes them very conspicuous. They vary in size from a pinpoint to that of a large cherry or almond. In many the blood sinuses occupy so large a part of the gland that they resemble blood clots. Their gross appearance varies greatly owing to the different proportions between the amount of lymphoid tissue and the size of the blood sinuses in different glands. On microscopical examination they show a great variation of structure in regard to the amount and arrangement of the lymphoid tissues and the number, size, and course of the blood sinuses. The capsule of the gland is usually very thin and contains yellow elastic tissue and unstriped muscle. The lymphoid tissue is often very scanty, consisting of small islands lying in the large blood sinuses, or, on the other hand, the greater part of the gland may be composed of lymphoid cells while the sinuses are small. In the large glands trabeculæ of connective tissue pass from the capsule toward the centre of the gland. The sinuses are usually large and prominent, and in the majority of cases make up the greater part of the organ. They are both peripheral and central, with communicating branches, and are traversed by a coarse reticulum, which may be very scanty or so close and mesh-like as to give an appearance resembling spleen pulp. The reticulum is lined throughout with flattened endothelium. The lymphoid portion shows usually a division into cortical and medullary zones. Germinal centres may be present in the cortical portion, and in these numerous mitotic figures may be found. In the medullary portion the lymphoid tissue is usually arranged in columns between the blood sinuses. The cells of the lymphoid areas are chiefly lymphocytes, but large mononuclear cells, mononuclear eosinophiles, transitional and polynuclear forms are numerous. Many of the cells of the reticulum and also of the endothelial cells lining the blood sinuses show a mast-cell granulation. In the central sinuses large mononuclear phagocytes are found in great numbers in the meshes of the reticulum, and these usually contain disintegrating red cells and blood pigment. The glands are supplied by numerous large arteries which on entering the organ quickly break up into small vessels feeding the sinuses.

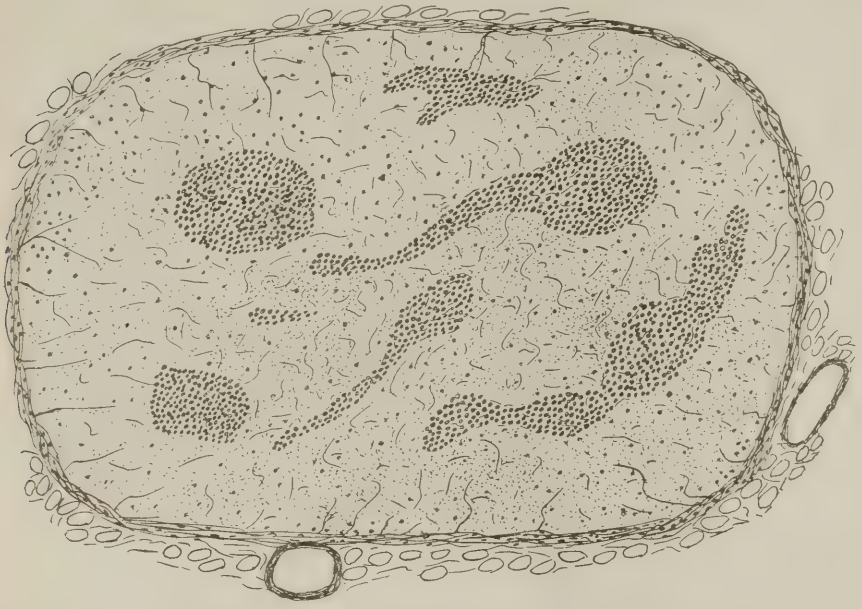

FIG. 2436.—One of the varieties of Hæmolymph Gland from Sheep. The blood-sinuses form the greater part of the gland; the small, irreguar islands of lymphadenoid tissue are surrounded on all sides by blood-sinus. Camera lucida drawing. Leitz objective 3; eye-piece No. II. Reduced one-third.

Sheep.—The hæmolymph glands are as large and prominent in this animal as in the steer, and in structure closely resemble those found in that animal. As a rule, they contain more lymphoid tissue, and the sinuses are relatively smaller. Their capsule is also more delicate.

The type with central lymphoid tissue and peripheral sinus is more common than in the ox. Phagocytes containing red cells and pigment are also less common, and the degree of hæmolysis is evidently less. Giant cells resembling those of the bone marrow are not infrequently found in the reticulum. A very remarkable feature is the large number of mast cells present; in many glands nearly all of the cells in the central lymphoid area may show this granulation. Germinal centres are not so numerous as in the glands of the steer. Red blood cells are found throughout the reticulum of the lymphoid areas.

Horse.—The hæmolymph glands of the horse have received but slight attention. They have been found chiefly in the neighborhood of the kidneys, no thorough study of the prevertebral region having been made. They appear as dark-red bodies of varying size and shape, the largest about 2.5 cm. in diameter, the average diameter being about 1.5 cm. On section they resemble very closely the glands of the sheep; but usually contain a larger amount of lymphoid tissue which is grouped in regular nodes, each of which is surrounded by a well-defined blood sinus, usually of uniform width. Cells containing disintegrating red cells and blood pigment are numerous, more so than in the case of the steer and sheep.

Goat.—Hæmolymph glands similar to those in the steer and sheep are stated to have been found in this animal, but no detailed description has been given of them.

Pig.—The first observations of hæmolymph glands were those made by Leydig in 1857, on the gross appearances of glands lying along the thoracic aorta in the pig, which bore a close resemblance to splenic tissue, and were regarded by him as intermediate structures between lymphatic glands and the spleen. Hæmolymph glands are also mentioned by Clarkson as occurring in this animal, but no description of their microscopical appearance has ever been published.

Dog.—Hæmolymph glands occur constantly in the prevertebral peritoneal fat, along the brim of the pelvis, and near the renal vessels. They may be of large size. In puppies they resemble closely those of the sheep; but in older dogs they are not very easily distinguished by the naked eye from ordinary lymphatic glands, in this respect being similar to those of the human body. They may often be recognized by a reddish peripheral zone or by red streaks corresponding to the blood sinuses. Phagocytes are numerous, and hæmolysis may occur to a great degree as shown by the large amounts of blood pigment present.

Rat.—Small oval or lenticular hæmolymph glands can almost always be found at the lower border of the pancreas, near the kidneys, and in the gastrosplenic omentum. The sinuses are both peripheral and central; and are of large size. They are usually filled with red cells; but may be partly or wholly empty. Phagocytes are numerous, and the evidences of hæmolysis are usually marked. The lymphoid tissue consists of both cortical and medullary zones, the former very dense but showing no germinal centres.

Guinea-Pig.—Hæmolymph glands have been observed in this animal by workers in the writer's laboratory. They occur in the prevertebral tissues as minute points usually too small to be recognized by the naked eye. Their microscopical appearance is very similar to that of many of the hæmolymph glands in man. The sinuses are small and are usually partly collapsed, the lymphoid areas are dense and only rarely show germinal centres.

Chicken.—Dark red glands resembling hæmolymph glands to the naked eye have been found in the abdominal fat, near the stomach, and below the rectum. On microscopical examination the greater part of the gland is found to be composed of blood sinus filled with nucleated red cells. There are numerous communicating branches between the central and peripheral sinuses. Pigment and phagocytes containing red cells are abundant. Red cells are numerous throughout the reticulum of the lymphoid areas.

Turkey.—Glands similar to those in the chicken are found also in the turkey.

Fishes.—The head kidney of certain Teleostean fishes is analogous in structure to the hæmolymph glands of the higher vertebrates, being composed of irregular masses of lymphoid tissue separated from each other by blood sinuses. The peripheral sinus is of large size.

Hæmolymph glands have also been sought in the *monkey, rabbit, cat, squirrel, mouse, hedgehog, mole, pigeon, parrot, duck, frog, toad,* and many fishes without success. As these investigations were based almost wholly upon naked-eye appearances, it is highly probable that careful microscopical investigation of the tissues of these animals will show them to be present.

Man.—Lymphoid structures containing sinuses filled with red blood cells are constantly present in the human body. To the naked eye they are not nearly so prominent as the glands of the sheep and steer because of the fact that their blood sinuses under ordinary conditions are more or less collapsed after death. Those possessing large sinuses are dark red in color; those with small or collapsed sinuses are recognized by their dark peripheral zone and red streaks corresponding to the blood sinuses. The search for these glands may be greatly facilitated by fixing the prevertebral tissues in four-per-cent. formalin, which bleaches other tissues, but darkens the blood-containing areas. In this way the blood sinuses are brought out very much more distinctly.

The human hæmolymph glands vary greatly in location, number, and size, seldom occurring in exactly similar manner. They are larger and consequently more easily found in early adult life than in old age, becoming atrophic in late years. They are present in the newborn. No difference has been observed in their occurrence in the sexes. They lie for the greater part deeply embedded in fat tissue, and possess a very rich vascular supply. The average size is that of a small pea; their relative proportion to ordinary lymphatic glands is 1 to 20–1 to 50, but in some cases they are found in such large numbers as to suggest the possibility of new formation or of resting glands taking on an active state.

On microscopical examination the human hæmolymph glands show an exceedingly great variation in structure. It would seem inadvisable to attempt to classify these variations, inasmuch as confusion would result from the numerous transition forms found. Broadly, two distinct types may, however, be distinguished, and to these I have applied the terms *splenolymph glands* and *marrow-lymph glands* as indicating their structure and probable function. It must be understood that there are no hard-and-fast lines between these types, all possible transition forms existing between them, as also between them and ordinary lymphatic glands.

The splenolymph gland is the more common form and is found chiefly in the neighborhood of the solar plexus, adrenal and renal vessels, and in the deep tissues of the cervical region, and occasionally in the mediastinal region, omentum, and mesentery. These glands are usually round, possessing a distinct hilum into which a large plexus of vessels passes. The capsule of connective tissue contains unstriped muscle and yellow elastic tissue. It may be very thick in proportion to the size of the gland, but not infrequently is very thin and delicate. From the capsule trabeculæ of varying size run into the organ cutting it up into irregular lobules; in small glands no distinct trabeculæ may be present. Immediately beneath the capsule there is a blood sinus of varying width which usually runs entirely around the periphery of the gland, but very often only for a portion of the way, being frequently interrupted by masses of lymphoid tissue reaching to the external capsule. Branches of the peripheral sinus run toward the centre of the gland accompanying the trabeculæ. In the central portion they often become very large and prominent. The lumen of the sinuses is traversed by a coarse reticulum through the meshes of which the blood circulates. In

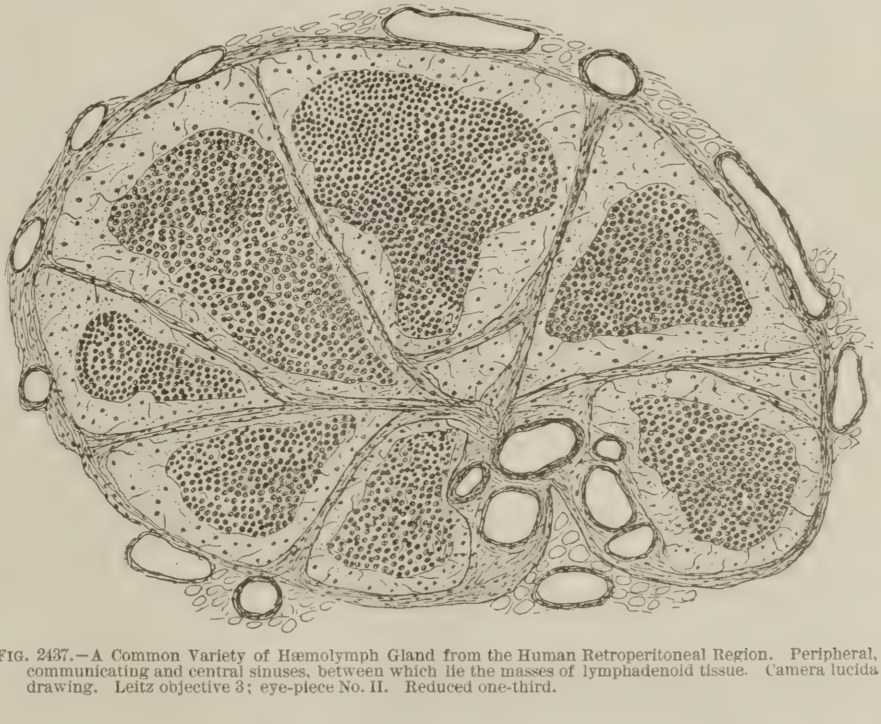

FIG. 2437.—A Common Variety of Hæmolymph Gland from the Human Retroperitoneal Region. Peripheral, communicating and central sinuses, between which lie the masses of lymphadenoid tissue. Camera lucida drawing. Leitz objective 3; eye-piece No. II. Reduced one-third.

the large central sinuses the reticular meshwork may at times be very scanty.

The reticulum of the sinus appears, in part at least, to be lined with endothelial cells, but these are with great difficulty made out, and in many places the blood seems to be in direct contact with the reticular surfaces. The circulation is therefore of the type described as sinusoidal. The nuclei of the cells of the reticulum stain much more lightly than those of the neighboring lymphoid tissue. There is apparently a direct continuation of the sinus reticulum with the reticulum of the lymphoid areas; and the latter may be regarded as the same structure enclosing in its meshes masses of lymphocytes. The number and size, as well as the general arrangement of the blood sinuses, vary greatly, so that scarcely any two glands resemble each other in these respects.

The lymphoid tissue lying between the blood sinuses resembles that of the spleen or ordinary lymphatic gland. It varies very much in amount, sometimes forming a mere network between the sinuses, while in other cases it may form the chief part of the gland. Usually the greater mass of lymphoid tissue is toward the periphery, forming the inner border of the peripheral sinus; but frequently extending to the capsule, breaking up the peripheral sinus into small sections that run for a short distance only. Small round collections of lymphoid cells resembling splenic follicles are often seen. These occur more frequently at or near the periphery, but they may occasionally be found near the central portion of the gland. They may be partly or wholly surrounded by the blood sinus. The cells in the central portion of the follicle stain more lightly than those at its periphery. Serial sections show that these nodes are almost perfectly round in the majority of cases. Usually they possess no arterial relations, but occasionally a small capillary is found in them which under certain pathological conditions may become gradually converted into a small arteriole with thickened walls. The resemblance in this case to the splenic follicle is very complete.

The cells of the lymphoid area are for the greater part small lymphocytes. These vary greatly with respect to the relative size and staining power of the nucleus and the relative amount of protoplasm. Next to the small lymphocytes the large mononuclear leucocytes are the most common form present. These also vary much in size, form, and staining power. Transitional and polynuclear leucocytes are also present in varying numbers. A small number of basophile and mononuclear eosinophiles is also usually present; mast cells are rare in the majority of cases, but occasionally a gland may be found in which the majority of the cells of the central portion are mast cells, as is so frequently the case in the hæmolymph glands of the steer and sheep.

The reticulum of the lymphoid areas resembles that of the blood sinuses, and is directly continuous with it. In its meshes lie the cells of the lymphoid tissue and also numerous red blood cells. The latter fact suggests the presence in the lymphoid tissue of very fine blood spaces similar to those in the spleen pulp, but differing from the latter in that the blood spaces are smaller and the reticulum is more dense. The reticulum of the large sinuses is much more abundant and of a coarser mesh than that of the lymph sinuses of the lymphatic glands. Small fibrillæ of elastic tissue and unstriped muscle may be scattered through it. In its meshes there are constantly present large mononuclear phagocytes containing disintegrating red cells and blood pigment. These cells are also found in the reticulum of the lymphoid tissue in connection with free pigment; but they are always more numerous in the reticulum of the medullary sinuses than elsewhere. Under normal conditions their number in individual glands varies greatly, the appearances suggesting a possible cyclical function of hæmolysis. Glands containing many of these cells may be found side by side with others whose reticular spaces contain but few. The same appearances are found in the hæmolymph glands of the lower animals, particularly in those of the dog and rat. Multinuclear giant cells, eosinophile, basophile, and mast cells may at times be found in the reticular meshes. The origin of the phagocytes has not yet been definitely determined; they may arise either from leucocytes or from the endothelial cells lining the reticulum.

Scattered masses and droplets of a fuchsinophile hyaline substance are often found throughout the lymphoid tissue; they are usually most numerous toward the periphery of the gland. They are frequently seen as highly refractile spherules lying in the meshes of the reticulum or enclosed in phagocytes. They are evidently the product of the destruction of red cells, as all stages of their formation can be found. In some cases the spherules are seen partly extruded from the phagocyte. They frequently give an iron reaction, especially those found in phagocytic cells.

MARROW-LYMPH GLANDS.—This type of hæmolymph gland is of very much less frequent occurrence in the normal body; but is much more prominent in certain pathological conditions, suggesting the possibility of resting glands or new formations. In some cases they appear to arise directly out of adipose tissue. They have been found only in the retroperitoneal region, along the vertebræ and brim of pelvis, and always in close proximity to the large vessels, abdominal aorta, vena cava, common iliacs, adrenal and renal vessels. They are present most frequently behind the aorta or between it and the vena cava. These glands are usually flattened and elongated, their greatest dimension lying parallel to the axis of the neighboring vessel. They may possess a distinct hilum, but the number of vessels entering is not so great as in the case of the splenolymph gland. Lymph vessels are also found in connection with these glands. Not rarely the marrow-lymph gland is found as a slender cylinder several centimetres in length embedded in fat. On section these glands are white or pinkish in color with fine red streaks corresponding to the course of the blood sinuses. Their consistence is very soft, and on section they present an almost homogeneous surface.

The capsule is thin and contains but little unstriped muscle and yellow elastic tissue. Delicate trabeculæ run from it toward the centre of the gland. Beneath the capsule there is a peripheral blood sinus of small size which usually runs entirely around the gland, and from this there are narrow branching sinuses accompanying the trabeculæ toward the centre of the gland. All of the sinuses are filled with a coarse reticulum through the meshes of which the blood circulates. Dilated sinuses as in the splenolymph glands are not present. The course of the sinuses is distinctly shown by the lighter staining nuclei of the reticulum and the presence of red cells. Lymph sinuses may also be present. Between the sinuses lies the lymphoid tissue arranged in irregular lobules. It is in much greater amount than in the case of the splenolymph glands. Throughout the lymphoid tissue, near the central portion of the gland, fat cells are present, either singly or in small groups. This may be regarded as one of the most striking characteristics of this type. Collections of cells resembling follicles are not present. The reticulum of the lymphoid areas is more delicate and scanty, and contains but little elastic tissue. The cells of the lymphoid areas present a much more striking variety of form and staining properties than in the splenolymph glands. Mononuclear eosinophiles and mast cells are more numerous; and multinuclear as well as large mononuclear forms with deeply staining knobbed nuclei may be present. Giant cells resembling those of the bone marrow are occasionally found, and in certain pathological states of the blood may be very numerous. No nucleated red cells have been found under normal conditions. Phagocytes containing red cells, pigment, fuchsinophile, hyaline bodies, and leucocytes occur to a less extent than in the splenolymph glands. Numerous red cells are found scattered throughout the reticulum of the lymphoid tissue suggesting the presence of smaller blood spaces.

Transition forms between spleno- and marrow-lymph glands are found, and also between the latter and ordinary lymphatic glands. The various forms found are such as to suggest the idea that hæmolymph glands are not permanent structures in any one form, but possibly show a certain amount of fluctuation. Thus the blood sinuses may become increased in size by a decrease of the lymphoid portion, while, on the other hand, an increase of lymphocytes may occur at the expense of the blood sinuses.

Circulation. — The exact mode of circulation in the hæmolymph glands has not yet been worked out. It is probable that the arteries entering the hilum quickly divide into smaller branches which, passing toward the periphery, empty into the blood sinuses from which the blood is again gathered into veins which pass out at the hilum or obliquely through the capsule. The circulation in the sinuses is of the type known as sinusoidal, only the endothelium separating the blood from the cells in the reticular meshes. The current in these spaces must be very slow, and a long period of time must be required for the complete circulation through the intricate meshes of the reticulum crossing the sinuses. The relations of the lymphatic and blood systems in these glands are also unknown. It is possible that, in the human body at least, a mixture of blood and lymph, the so-called hæmolymph, may be present in the sinuses, and that direct communication between the two systems occurs in these glands.

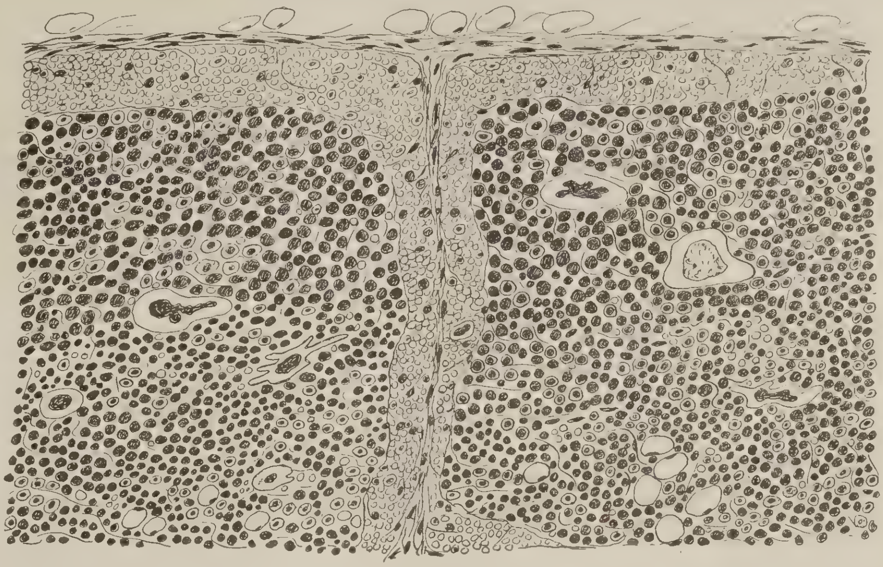

Fig. 2438.—Portion of Human Hæmolymph Gland (Marrow-lymph Gland) from Retroperitoneal Region of an Individual who had Died of Hemorrhage from the Nose. In the lymphadenoid tissue are giant cells resembling those of the marrow, nucleated red cells, mononuclear eosinophiles, etc. A number of fat cells are also seen scattered through the lymphadenoid tissue. Leitz objective No. 7; eye-piece No. IV. Reduced one-third.

Development.—No work has yet been done upon the development of these structures. They are found as fully developed organs in the new-born child, and have been found at an early period in the fœtal calf. They are without doubt to be regarded as individual organs whose early stage of development runs parallel with those of the lymphatic glands. Under certain pathological conditions it is possible that they may be developed from ordinary lymphatic glands or from adipose tissue in compensation for the spleen or bone marrow.

Function.—The hæmolymph glands are so numerous in the steer and sheep that their function is obviously of importance. In other animals and in man, while constantly present, they do not under ordinary circumstances attract attention through either their numbers or their size. The constant presence of phagocytes containing disintegrating red cells and pigment would indicate that extensive hæmolysis is one function carried on in these structures. As before mentioned, the presence of glands containing many phagocytes in their sinuses side by side with those whose sinuses contain only red cells would indicate a cyclical function; and there are many other appearances to suggest this. Under normal conditions no evidence of the formation of red cells has been observed, unless the occasional presence of bone-marrow giant cells may be taken as an indication of this process. The presence of these in the sinuses may, however, be explained on the assumption of giant-cell embolism. Under pathological conditions, such as anæmia and leukæmia, the hæmolymph glands, particularly those described as marrow glands, show evidences of increased functional activity in the hyperplasia of all the glandular elements and the increased number of mitoses in the lymphoid cells. In addition large numbers of giant cells may be found in the reticulum of the sinuses and in the lymphoid areas, evidently formed in the gland; also nucleated red cells, myelocytes, etc., may be present, so that the gland may come to resemble lymphoid marrow. These changes are not shared by the other lymph glands of the body. The hæmolymph glands are also to be regarded as important centres of leucocyte formation. After splenectomy or in certain pathological conditions of the spleen the splenolymph glands may compensate for this organ through hyperplasia and increased hæmolytic activity. In short, the hæmolymph glands normally possess a hæmolytic function and give rise to leucocytes; under pathological conditions they may also become centres of red-cell formation.

Pathology.—The more common pathological processes, such as congestion, inflammation, tuberculosis, metastases of malignant tumors, etc., have been found affecting these glands in common with the ordinary lymphatic glands. In a limited group of conditions such striking changes occur that they must be regarded as specific in character. These changes are confined entirely to cases showing more or less marked pathological alterations of the blood.

Anæmia.—In all of the cases of anæmia examined either the splenolymph or the marrow-lymph glands showed changes of greater or less extent. These changes varied with the nature and degree of the anæmia.

Post-hemorrhagic Anæmia.—In a case of fatal anæmia following repeated and prolonged attacks of epistaxis the only lymph glands showing change were those of the retroperitoneal region, particularly those in the neighborhood of the solar plexus. These were moderately enlarged, of a pink color and soft consistence. On microscopical examination they presented a structure resembling in the most striking way the lymphoid marrow. Throughout the reticulum of the sinuses and lymphoid areas were numerous giant cells in all respects resembling those of the marrow. The findings admitted of but one interpretation: these giant cells must have been formed within the gland, most probably from the reticulum or the endothelium lining it. Large numbers of mononuclear eosinophiles, nucleated red cells of large and small size, large mononuclear leucocytes corresponding to myelocytes, and all possible varieties of transitional forms were also present. The bone marrow of this case showed scattered areas of lymphoid marrow, and in both the liver and spleen changes were found suggesting a return to a fœtal mode of blood formation. Numerous nucleated red cells were present in the blood. The remaining lymph glands showed only a fibroid hyperplasia.

Secondary Cachectic Anæmia.—In a large number of cases examined showing a more or less severe cachectic anæmia both marrow- and splenolymph glands showed increased hæmolysis, but no evidences of the formation of red blood cells were present.

Splenic Anæmia.—In a case of splenomegaly with severe anæmia, the patient dying after splenectomy, numerous minute nodes of lymphoid tissue were found scattered throughout the adipose tissue of the mesentery and retroperitoneal region. The majority of these possessed a small arteriole showing a much thickened wall; in some cases the lumen was completely obliterated by the proliferation of the intima. The new tissue blocking the vessel in many cases showed a hyaline change, and the concentric arrangement in some instances bore a strong resemblance to the thymus corpuscles. In some cases the hyaline tissue had undergone calcification. This new formation of lymphoid tissue resembles very much the changes found in the omentum of animals whose spleens had been experimentally removed, and is probably to be interpreted as compensation for the diseased spleen. The splenolymph glands in this case showed also such changes that they resembled splenic tissue, both to the naked eye and on microscopical examination, being regarded at the autopsy as accessory spleens.

Pernicious Anæmia.—In five cases of pernicious anæmia examined the changes in the hæmolymph glands were so constant and so marked that the writer regards them as specific in nature. In the more rapidly progressing forms the number of splenolymph glands is so great that they must be regarded either as new formations or as resting glands become active. In one case over sixty of these glands were removed from the cervical, thoracic, and retroperitoneal regions; and in another over thirty from the retroperitoneal region alone. The glands are enlarged and darker in color, often a chocolate brown. On microscopical examination the central and communicating sinuses are found almost filled with large phagocytes containing red cells and pigment. The processes of hæmolysis are increased to an extraordinary degree, particularly in the rapidly progressing forms. The spleens in these cases showed but little evidences of hæmolysis, while liver and kidneys showed marked hæmosiderosis. No evidences of increased activity on the part of the bone marrow were found; on the contrary, in all of the cases there was marked atrophy of the red marrow associated with osteoporosis and the formation of cystoid cavities filled with liquid fat.

In one case of progressive anæmia extending over three years, characterized by repeated severe attacks of epistaxis, hæmatemesis, and bloody stools, the only pathological changes of importance found on autopsy were in the retroperitoneal lymph glands. These were enormously enlarged, forming an almost continuous double row on each side of the abdominal aorta and diverging below along the brim of the pelvis. Each gland was 3 to 4 cm. in length and 1 to 2 cm. in thickness. They were almost cylindrical, somewhat flattened, and were dark red in color, almost black. On section the blood flowed freely from the greatly dilated veins. On microscopical examination a great hyperplasia of the lymphoid tissue was found, extending beyond the original capsule of the gland into the surrounding fat tissue. The appearances suggested strongly the possibility of a direct conversion of fat into lymphoid tissue. Numerous mononuclear eosinophiles, nucleated red cells, and occasional giant cells were present throughout the reticulum of the lymphoid areas. Mitotic figures were numerous. The presence of blood sinuses proved these glands to be hæmolymph glands of the marrow-lymph type, and the process was interpreted as a compensatory hyperplasia for the bone marrow which was atrophic and cystoid.

Leukæmia.—In a case of mixed leukæmia an enormous hyperplasia of the marrow-lymph glands similar to the above was found. On microscopical examination the blood sinuses were found filled with giant cells which were also scattered throughout the lymphoid areas. Mononuclear eosinophile cells, nucleated red cells, myelocytes, and an almost infinite variety of leucocytes, especially well shown in specimens stained with the tri-acid stain, made up the lymphoid portions. The resemblance to lymphoid marrow was very close, as in the case of fatal anæmia following epistaxis. The other lymph glands showed but slight enlargement due to the increased number of leucocytes present. The bone marrow showed but little lymphoid increase; the spleen was greatly enlarged. The changes in the marrow-lymph glands are to be interpreted in this case also as being evidence of the ability on the part of these glands to take up the blood-forming function of the bone marrow.

Leucocytosis.—In cases of pyæmia showing marked leucocyte increase the hæmolymph glands exhibit evidences of increased activity in the cells of the lymphoid areas, as shown by numerous mitoses. The mononuclear eosinophiles are also increased in number, and nucleated red cells and giant cells may also be found.

Experimental Pathology. — In animals whose spleens have been removed the hæmolymph glands show hyperplasia and evidences of increased hæmolysis. In poisoning with hæmolytic agents such as pyrogallic acid, muscarin, toluylendiamin, etc., these glands show greatly increased hæmolysis, the sinuses being packed with phagocytes containing red cells and pigment.

Summary.—By the above cases it is shown that under pathological conditions of either the spleen or bone marrow, the hæmolymph glands may assume either a hæmolytic or a hæmatopoietic function; and that in all conditions characterized by increased hæmolysis the chief seat of the blood destruction appears to be located in the sinuses of these organs. *Aldred Scott Warthin.*

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HÆMOPERICARDIUM.—Blood in the pericardium is a rare condition and of small clinical interest.

Etiology.—In tuberculous and malignant diseases of the pericardium, just as in similar diseases of the peritoneum, the exudate is usually bloody. By hæmopericardium is meant a hemorrhage into the pericardium. This accident occurs under the following conditions:

(1) As a result of traumatic injury from without, or by foreign bodies penetrating the œsophagus from within.

(2) Such hemorrhages have been found associated with scurvy, purpura, leukæmia, and allied conditions.

(3) From rupture of the heart or a cardiac aneurism.

(4) From rupture of an aneurism of the aorta or pulmonary artery. The first part of the aorta is usually involved and it may be by only a pinhole rupture.

(5) From rupture of smaller vessels, namely, one of the coronary arteries, or of vessels in a new growth.

Anatomical Characters.—The quantity of blood varies much. It is greater when the opening in the aorta is small. When an aneurism bursts into the pericardium the average amount of blood usually found is said to be about seven ounces. When the hemorrhage takes place through a small hole, it may reach twenty-four ounces. A traumatic case has been reported in which over six pints of thin, dark, fluid blood were removed from the pericardium in the course of three hours. The patient recovered. The blood may appear as a soft, red, jelly-like clot. A variable amount of serum may have separated from it.

Clinical History.—The condition may occur suddenly. The associated disease, such as aneurism, may have been previously demonstrated. When the hemorrhage takes place through a large rent, immediate or very rapid death usually occurs, either from the effects of the hemorrhage, or from paralysis of the heart. The fatal event may be preceded by grave cardiac symptoms. When the accumulation takes place gradually the patient may live for some time, complaining of cardiac oppression or pain, dyspnœa, and faintness.

Physical Signs.—These are not likely to be noted in the sudden cases. When the progress is slower there is a more or less rapid increase in the area of cardiac dulness; the apex beat disappears and the heart sounds become weak.

Treatment.—In the majority of cases treatment is limited to the relief of symptoms. Hæmostatics are useless. In the protracted cases cardiac stimulants may prolong life. A few patients recover as a result of aspiration of the pericardial sac. *James Rae Arneill.*

HÆMOPHILIA.—(Synonyms: Hemorrhagic Diathesis or Idiosyncrasy, Hæmorrhaphilia, Hæmatophilia, Heredity Hemorrhage; Ger., *Hämophilie, Bluterkrankheit, Blutsucht, Blutungssucht;* Fr., *Hémophilie.* Otto, an American physician, gave the name Bleeder [Ger., *Bluter;* Fr., *Homme saignant*] to an individual patient.)

Definition.—An hereditary and congenital disease, characterized by a tendency to frequent, obstinate, and prolonged hemorrhages, external or interstitial, spontaneous or traumatic, associated with swelling of the joints.

History.—Our knowledge of this disease is modern. Its historians have been able to find the records of but few probable cases or families prior to the present century, and even these, with the exception of the cases reported by Hochstetter and Sir W. Fordyce, may all be considered doubtful examples, and Legg cannot admit Banyer's case to be beyond doubt. It was left for American physicians accurately to fix the characteristics of the disease. Otto, E.H. Smith, Hay, the Buel brothers, and Coates, in the early part of the last century, and Hughes, Gould, Harris, Hutchinson, Holton, and Dunn, in the past thirty years, have been the chief contributors to its literature. The early writers first demonstrated its hereditary nature. In the second and third quarters of the last century the Germans were prolific workers. Nasse, Rieken, Schönlein, and others, were of the earlier writers. Wachsmuth's monograph, Lange's statistics, Virchow's complete description in his "Handbuch," the monograph of Grandidier, the most complete published, and the article in "Ziemssen's Handbuch," by Immermann, familiarized modern German physicians with the affection. The exhaustive monograph of Legg is the principal contribution made by any English physician.

Etiology.—Sex and heredity are the most important factors in the etiology of hæmophilia. It occurs with greatest frequency in the male, the ratio having been put as high as eleven males to one female. Females do not usually present typical cases, and danger to life is less in the latter sex.

Hereditary disposition is so essential that its absence in a supposed case is sufficient to negative the diagnosis, although, it is true, it is difficult, often impossible, to trace genealogy among the lower classes. Legg believes all or nearly all cases may be traced to an hereditary origin. It has been suggested that this hereditary tendency is the result of the intermarriage of near relations. The fact that it occurs largely among Germans and Jews favors this argument, for in both classes such marriages are common. A common ancestry for all bleeders has been assumed by some authors.

While the females are not the bleeders of a hæmophilic family, the disposition is transmitted through them. The mother, not a bleeder, will transmit the tendency to her sons. They in turn are not likely to conduct the disease to their children, but the tendency passes through the daughters to the grandson. The females that transmit the tendency are usually in perfect health, although cases have been reported, in rare instances, in which the mother, a bleeder, transmitted it to the children of both sexes. The cases are still more rare in which the father, a bleeder, will pass down the tendency to either the sons or the daughters, respectively. A male non-bleeder, in a hæmophilic family, seldom transmits the disease to his descendants. Transmission through the female line is the rule. It is said that the first-born of a family are less liable to become bleeders. This tendency to bleeding may continue for many generations. The Clitherow family, reported by Legg, have exhibited the tendency for two hundred years. The families of Tenna, Switzerland, trace the disposition through five generations.

One peculiarity of bleeder families that has been noted is the marked intellectual power of the individuals; another, the great fertility of the families. Although they have many children, few reach adult age, as the number is much lessened by death from hemorrhages in early life, the mortality at that period being very great.

The disposition to bleed, Grandidier believes, may gradually be lost in a family. He has himself seen one such example, and another has been reported by Legg.

It was noted above that among Germans hæmophilia is common. In fact, some think it a disease peculiar to the Anglo-Germanic races. Dunn's analysis of 219 families shows its distribution about as follows: Germany, 94; Great Britain, 52; North America, 23; France, 22; Prussia and Poland, 10; Switzerland, 9; and the remainder in other European countries. The condition is rarely found in the negro, as has been pointed out recently by Steiner (Johns Hopkins Hosp. Reports, 1900) who reports one case and refers to one other decribed by Hadlock.

Hæmophilia spares no social class, though cases are reported more frequently from the middle and lower classes. Its presence or absence is not influenced by geographical position, and the nature of the food is also without effect on it.

While it has been asserted of many cases of hæmophilia that they arose spontaneously, yet nothing is known of the circumstances contributing to their origin. Legg rightly criticises the case of Mutzenbecher, in which the disease was reported to have arisen *de novo.* A mother, suckling her child, received a great fright, after which the child nursed. Shortly afterward symptoms of hæmophilia developed. Two other sons, also bleeders, were subsequently born, a fact which renders very probable the hereditary transmission in this case.

The circumstances, aside from traumatism, influencing the occurrence of hemorrhage, or which may be the predisposing or exciting causes of the accident, in a person belonging to a hæmophilic family, are the age, the constitution, and the temperament of the individual; the time of day, the season of the year, and the climate. Hemorrhages have not appeared for the first time after the twenty-second year; it is rare for them to appear after the twelfth year, and in the larger number of instances the first attack occurred before the fifth year. Its most usual appearance is about the end of the first year. Hemorrhage from the umbilicus, after sloughing of the cord, is very rare.

Bleeders are always in good health except that they suffer from anæmia. They often have blue eyes, light hair, a thin skin, and prominent veins.

Instances are recorded in which the hemorrhages occurred most frequently at night. The winter season and a cold, damp climate favor attacks of hemorrhage.

Those who consider the disease to be an infectious condition have scanty evidence to support their view. Bacteriological examinations have been entirely negative, and the manifestations of the disease cannot be explained by the theory of infection.

SYMPTOMS.—The occurrence of frequent, obstinate, and prolonged hemorrhages, spontaneous or traumatic, with their sequelæ, and the joint manifestations, are the essential symptoms.

Legg makes three degrees of hæmophilia: in the first form, the most typical and severe, there is a tendency to every kind of hemorrhage, spontaneous or traumatic, interstitial or superficial. The joint swellings are also marked. In the second form, spontaneous hemorrhages only are present, with rheumatic pains. In the third degree spontaneous ecchymoses alone are observed. The first degree is most often seen in men, the second in women, and the third in members of bleeders' families.

External Hemorrhages.—These are usually capillary. Even a traumatic hemorrhage is of that nature. In one case (Blagden's) a vessel which had been ligated soon gave way on account of the thinness of its coats. One of the cases reported by Dunn had an ulcer in the nostril, from which the spontaneous hemorrhages would spring.

Spontaneous hemorrhages are often preceded by prodromal manifestations. These are usually the symptoms of plethora or nervous symptoms. In children great cheerfulness and liveliness, attacks of crying, morbid fears, and even convulsions, have been noticed. In adults, a good temper, with great restlessness and sensitive emotions, are seen. Pain is often complained of in the locality in which the hemorrhage is about to occur. These prodromal symptoms disappear after the hemorrhage sets in.

The seat of the hemorrhage in the spontaneous form varies with the age—in childhood, the nose and mouth are the most frequent localities; in adult life, in addition to these situations, the stomach, the bowels, the urethra, the lungs, the female generative organs, etc.*

Of interest, in regard to local origin, is the case observed by D. Hayes Agnew (quoted by Osler), in which hemorrhage occurred from cuts and bruises above the neck, but never from those below.

The frequency of occurrence of spontaneous hemorrhages varies. They may occur daily, or at intervals of days or weeks. Resal (Legg) points out two forms of spontaneous hemorrhages. In one they are small in quantity, but frequently repeated, occur without prodromal signs, and always from the same mucous surface. In the other form there are prodromes, the hemorrhage is excessive, and does not usually cease spontaneously. Just as it is impossible to estimate the usual frequency of occurrence, so it is difficult to calculate the length of time the hemorrhages may continue. It is variable, from a moment to weeks, the latter with varying intermissions. Epistaxis is the most fatal of all forms of spontaneous hemorrhages; it has proved fatal in twenty-four hours.

Traumatic hemorrhages are due to blows, cuts, scratches, etc. Even after the most trivial operation the hemorrhage may be fatal. The amount of bleeding from a wound varies in bleeders from time to time—at one time scarcely any hemorrhage will be observed; at another, with the same wound, the bleeding can scarcely be checked. So, too, families appear to differ as to the extent of injury they can suffer with impunity. In one family venesection can be performed; in another the application of blisters would be dangerous (Legg). A superficial lacerated wound is thought to be more serious than a deep, clean-cut one. The healing of a wound may occur with or without suppuration; a profuse bleeding, when it occurs, will prevent healing by first intention.

The amount of blood lost by either form of hemorrhage is sometimes enormous. The famous case of Coates lost half a gallon in twenty-four hours, and three gallons in ten days. Thore's case (Legg), that of a boy aged five, lost nearly a pound from a small wound.

The result of these repeated hemorrhages is a profound, and often fatal, anæmia. Digestive troubles also often develop afterward, and in some cases a depraved appetite has been observed (Buel's).

Severe palpitations, dyspnœa, vertigo, syncope, and other evidences of anæmia may be observed. Enlargement of the heart and systolic murmurs at the base and in the vessels of the neck may be detected. The urine after a hemorrhage frequently contains albumin. Fever has been observed, but is not constant.

Ecchymoses and Petechiæ, Interstitial Hemorrhages.—They may be spontaneous or traumatic. The spontaneous varieties may occur without external bleedings, or may precede a hemorrhage. They are seen in early childhood. They are similar in appearance to purpura, and are seated chiefly on the trunk and limbs. They vary from a pin's head to a quarter of a dollar in size, are tender on pressure, and on disappearing pass through the same changes that an ordinary traumatic ecchymosis does, and exhibit the same play of colors. The traumatic ecchymoses are larger than the spontaneous; they may cause death by hemorrhage into the connective tissue. Blood tumors—hæmatomas—may follow the slightest blow. They may become as large as a child's head and are of a bluish-black color. By some authors it is thought they may arise spontaneously.

Joint Affections.—Legg believes that the joint affections are sometimes due to traumatism. In other instances the origin is not understood, the exciting causes being exposure to cold or dampness, and variations in temperature, particularly in the spring and autumn. The larger joints, chiefly the knee-joint, are the ones affected. They become painful, hot, much swollen, soft, and boggy. Often the affection develops suddenly. Marked constitutional symptoms, as fever, anorexia, and general pains, attend the attack. The pain is increased by motion. The duration of the affection varies from a few days to many months. It may change from joint to joint, or the swelling may alternate with a hemorrhage. Once affected, the patient is liable on the slightest provocation to have a recurrence of the disease. Repeated attacks may lead to destructive lesions in the joints, with crippling and deformity.

Persons affected with hæmophilia often suffer from general rheumatic pains, which vary in degree with atmospheric changes.

It is said that some bleeder families are very sensitive to cold and dampness, and that bleeders are very susceptible to the action of mercury. They are not differently affected by various diseases than are non-bleeders. "They appear more liable to acute affections within the chest" (Legg). Rheumatism and scrofula are said to occur frequently; gout is very rare. Gangrene is especially liable to occur after traumatic hemorrhage.

MORBID ANATOMY.—The *blood* is usually normal. After a profuse hemorrhage or a series of small ones, it partakes of the nature of the blood of anæmia. Under these circumstances the white corpuscles have been found in excess, the red in smaller numbers, and the hæmoglobin reduced, *i.e.*, the natural result of hemorrhage. The fibrin is apparently not greatly diminished. The salts are said to be increased. Recent studies indicate an actually decreased coagulability of the blood.

There are no characteristic anatomical changes. Blagden called attention to the thinness and transparency of the vessels. One observer found the large vessels smaller than normal; another, an increase in the size of the superficial, in proportion to the central vessels (Immermann). Wilson thought that the arteries resembled the veins. Fatty degeneration of the heart has been found. Kidd observed proliferation of the endothelial cells in small arteries and veins, and "hydropic degeneration" of the muscular fibres. Klein, Ackland, and other observers fail to confirm these studies. The joints, when involved, are the seat of blood extravasation; not only the cavity but the tissues around are infiltrated. Bowlby has shown that the changes in the articular structures cannot be attributed to the mere effusion of blood. As in arthritis deformans, the cartilaginous covering of the articular ends becomes fibrillated, and in the parts most exposed to friction may be eroded and inflamed. There is also the same tendency to the formation of ecchondroses which in time may become osteophytes. Unlike arthritis deformans, fibrous adhesions may form, resulting in limitation of motion.

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* The following statistics are interesting, mainly from Grandidier, also quoted by Legg, and by Osler. Spontaneous Hemorrhages—localities and frequency: From the nose, 169 times; the mouth, 43; stomach, 15; bowels, 36; urethra, 16; lungs, 17; cerebral hemorrhage, 2; swollen place on scalp, 4; tongue, 4; finger-tips, 4; ear, 5; eyelids, 2; tear papilla, 3; female generative organs, 10; ulcer of skin, 2; navel (long healed), 2. Fatal hemorrhages have occurred from the following wounds: Blow on head, 11 times; slight scratches on skin or abrasion of dermis; laceration of frænum of the lip; slight cut in a duel wound, bite of the tongue (7 cases); fall on the mouth; blow on the nose; blow of a stone on the finger; cut in paring the nails; fall on the head with meningeal hemorrhage (2 cases, brothers); and rupture of the hymen on the wedding night.

Deaths after operations: Cutting of frænum linguæ, 1; leeching, 5; venesection, 4; blister, 2; extraction of tooth, 12; circumcision, 8; cutting umbilical cord, 4; vaccination, 2; fistula, stone, ligature of carotid, of radial, of ulnar, of femoral arteries, amputation of arm and of thigh, 1 each; phimosis, 2.

PATHOLOGY.—This is obscure. While a congenital fragility of the vessels is said to exist, it has never been proven. It has been observed that bleeders always suffer from prodromic symptoms, which are due to an increase in the volume of the blood. Hence, variability in the volume has been invoked as causal. Disturbed innervation, diminishing from time to time vascular tone, is thought by many to be the pathological factor. It is merely an hypothesis, as have been all suggestions thus far put forward regarding the pathology of hæmophilia. As suggested by Eichhorst, it may be possible that the changes in the blood are of a chemical nature, not to be discovered by our present methods.

DIAGNOSIS.—Many cases of a hemorrhagic diathesis occur, the exact nature of which it is difficult to determine. Especially is it so with this diathesis in women. If, however, there is no history of heredity, if the hemorrhages did not occur in early life, prior to twelve years, and if she should not transmit it to her sons, it is not likely to be a case of hæmophilia. The hereditary predisposition, the spontaneous and traumatic hemorrhages setting in early in life, and the joint symptoms, are conclusive evidence of the nature of a case. Cases arise, no doubt, in which heredity cannot be determined, and which may yet be the founders of a stock of bleeders. One of the writer's cases is possibly of this class. Since the age of five months spontaneous bleedings, often to syncope, have occurred; since puberty (the patient is now twenty-two years of age) plethoric prodromes have preceded the attacks. The patient undertook to learn carpentering, but had to give it up on account of traumatic hemorrhages. Extractions of teeth have caused serious hemorrhages. Annually the patient is afflicted with severe joint symptoms, rheumatic in character.

Umbilical hemorrhage in the new-born is not due, or but rarely, to hæmophilia, but is usually the result of liver disease or syphilis. The hemorrhagic conditions of the new-born, probably infectious in character, referred to as *transitory hæmophilia, spontaneous hemorrhage, or infectious hæmophilia of the new-born*, can be distinguished from true hæmophilia by their transitory character, the occurrence of spontaneous hemorrhages in different parts of the body, their acute course, their self-limited character, the early appearance of symptoms, and the frequency of umbilical hemorrhage, jaundice, and high fever. Purpura, simplex and hæmorrhagica, scurvy, peliosis rheumatica, toxic and septic purpura, must be excluded.

PROGNOSIS.—The first bleeding is rarely fatal. The younger the patient, the more grave the prognosis. Hæmophilia is more serious in boys than in girls, and more so in the delicate than in the strong. With advancing years the prognosis improves. Often, especially if the patient suffer from joint complication, the tendency to hemorrhage may disappear for a number of years. Long-continued oozing is a serious form of hemorrhage. The bleeding after the extraction of a tooth is very serious, as is also the hemorrhage from lacerated and contused wounds. Face injuries are also serious.

TREATMENT.—If a person suffering from hæmophilia present the symptoms indicative of an attack of hemorrhage, an active purgative should be administered and the patient put on low diet without stimulants. Often an attack is averted thereby. Otto advised the sulphate of soda; Fordyce, the sulphate of magnesia. Venesection has been resorted to under similar circumstances. If a spontaneous hemorrhage occur, opinions differ, whether to check it or not is advisable. Wachsmuth, Legg, Frish, and others claim that apoplectic symptoms or grave dyspnœa may arise if it is checked. The latter author advocates venesection. It is certain, if the hemorrhage is not too profuse, a bleeder always feels better after it. When it is decided to check the hemorrhage the method of treatment depends largely on the seat of the bleeding, and is similar to the plan adopted in the traumatic varieties if it arise from external parts. Internal remedies are more frequently required in the spontaneous form, but are used in both. Ergot or ergotin, the latter by mouth or hypodermatically, hamamelis, gallic acid, opium, alum, turpentine, and preparations of iron, have been used with benefit. Legg recommends the tincture of the perchloride of iron, thirty to forty minim doses every two hours, together with a purge if there is no intestinal hemorrhage. Transfusion may be resorted to when external and internal remedies are used without avail.

The principles that govern the treatment of any traumatic hemorrhage apply in a case of hæmophilia. A few of the usual methods must be modified as follows: Ligation of the artery should never be performed; the actual cautery should be used as a last resort only; care in exercising pressure should be used on account of the possibility of ecchymoses and sloughing taking place; plugging of the nares should only follow failures to control bleeding by other means. The wound should be cleansed, rest secured, compression used, the artery pressed upon if possible, cold, and especially ice, or very hot water applied to the bleeding parts, and finally, styptics, as the astringent salts of iron, preferably Monsel's solution, the nitrate of silver, alum, and other well-known astringents should be tried. The famous styptic of Pancoast is a clean and most efficient application. Gelatin in five-per-cent. solution may be used. A hemorrhage from the extraction of teeth may be controlled by means indicated above, by replacing the tooth in its socket, by taking a plaster-of-Paris cast of the jaw, by retaining the jaw in position by a roller bandage, or finally by the cautery.

Recently the physiological principles of coagulation have been applied to the treatment of hemorrhage. A. E. Wright recommends the local use of a solution of fibrin ferment in an aqueous calcium-chloride solution. Schmidt and von Manteuffel have controlled a hemorrhage after tooth extraction by application of Schmidt's zymoplastic substance after cocainization. For the epistaxis Wright also recommends the inhalation of carbon dioxide through the nostrils.

Traumatic hemorrhage must be prevented by avoiding all surgical operations on a person affected with hæmophilia, unless life is in peril, and by preventing him from engaging in any occupation in which he is liable to receive an injury. A tooth should not be extracted under any circumstance.

In the interval between the hemorrhages the patient should use a generous but non-stimulating regimen, should live in the fresh air, should avoid exposure to cold and dampness, and should be free from all excitement. Iron and cod-liver oil should be used, unless plethora should ensue. The prolonged use of the Rock Bridge alum water, of Virginia, has been of service in some cases, in reducing the frequency of hemorrhages.

Surgical principles must be invoked in the treatment of the joint affections. Residence in a damp locality, or exposure to cold and dampness is particularly likely to cause and aggravate these complications. If they are obstinate, a warm, dry climate must be sought.

The marriage of the daughters of a family of bleeders should be prohibited. In this way only can the advance of the disease be checked. If the brothers are marked subjects of the disease their marriage should be prevented.

J. H. Musser.
R. M. Pearce.

HÆMOPTYSIS.—Etymologically considered, the word hæmoptysis signifies the expectoration of blood, without regard to its source or quantity. Practically, however, the term has come to indicate the expectoration of pure, or of almost pure blood, emanating from the respiratory organs, viz., from the larynx, trachea, bronchi, or lungs. The expectoration of rusty, prune juice, or greenish sputa, in pneumonia; of blood-streaked sputa in bronchitis; of jelly-like masses, as in cancer; or of chocolate-colored material in hepatic abscess, does not, therefore, properly constitute an example of hæmoptysis in the ordinary acceptation of the word. The term is, however, applied by some authors to the expectoration of blood in sufficient quantities to be microscopically discovered, even if the sputa containing it be largely composed of other constituents.[1] The spitting of blood which, having been extravasated at points more or less remote from the respiratory organs, and having reached the pharynx, has gravitated into the air passages (as in hæmatemesis, and in buccal, œsophageal, or nasal hemorrhages), may be designated as pseudo-hæmoptysis or spurious hæmoptysis. The expectoration of blood follows bronchorrhagia and pneumorrhagia in so large a proportion of cases that only hæmoptysis due to these causes will be considered in this place, the reader being referred, for information regarding laryngeal and tracheal hemorrhages, which are comparatively rare, to the articles in this HANDBOOK treating of diseases of the larynx and trachea. An absolute discrimination between bronchial and pulmonary hemorrhage being very difficult, and of slight importance from a therapeutical standpoint, will not be insisted on in the present article. Furthermore, as the etiology and pathology of hæmoptysis are fully discussed under other headings (the various diseases of the heart, lungs, bronchi, larynx, etc.), it seems best to omit, in the present article, all discussion of this part of our subject.

SYMPTOMATOLOGY.—The clinical history of hæmoptysis embraces: I. Prodromal Symptoms; II. Actual Symptoms, or those of the attack, and III. Consecutive Symptoms, or sequelæ.

I. *Prodromal Symptoms.*—Premonitory symptoms are often absent in hæmoptysis, particularly if it be due to traumatic causes, to the rupture of an aneurism, or to incipient phthisis.[2] Under these circumstances the hemorrhage occurs either without an evident exciting cause, while the patient is quiescent, or it is precipitated by some physical effort, such as lifting, riding, running, or dancing. Subjective precursory phenomena generally precede hæmoptysis from active or passive congestion, and in cases of recurrent hæmoptysis. The most noteworthy premonitory symptoms are cold extremities, accelerated pulse, vertigo, cephalalgia, epistaxis, thoracic oppression, constriction, distention or warmth, a dry hacking cough, vague general discomfort, slight dyspnœa, and cardiac palpitation. An objective prodromal symptom is cerebral congestion, accompanied by flushing of the face, throbbing of the carotids, and augmented rapidity and force of the pulse. Important suggestions relative to the possible occurrence of hæmoptysis may be derived from the previous history, particularly if this includes evidences of phthisis, of cardiac disease, or of one of the dyscrasiæ. Prodromes may be observed several days before a pulmonary hemorrhage, recurring at irregular intervals before the attack, or they may directly precede the hæmoptysis.

II. *Actual Symptoms, or those of the Attack.*—In an ordinary case of hæmoptysis, whether inaugurated by premonitory symptoms or not, the patient experiences a sensation such as might be referred to the trickling of a warm liquid beneath the sternum, perceives a saline, sweetish taste, and, on clearing his throat, expectorates blood without effort. Cough, attended by characteristic large, moist, tracheal and bronchial râles, now begins, or may have preceded the first bloody expectoration, and each paroxysm of coughing leads to the expulsion of a variable quantity of blood, which is generally fluid, arterial in color, of alkaline reaction, frothy from the admixture of air, and often mingled with mucus or muco-pus. If the quantity of blood be small, and its expulsion gradual, it is often venous, or even black in color, and more or less completely coagulated. Coagula emanating from the lung are usually of low specific gravity, on account of the air bubbles which they contain. Blood casts of the bronchi may be expectorated. The quantity of blood rejected varies within wide limits. In some cases only a few drachms are expectorated; in others, particularly in hæmoptysis from ruptured aneurisms, from phthisical or other cavities and in pneumorrhagia, several pounds may be rejected. If the blood is so abundant that it fails to find a ready exit through the buccal cavity, which rarely happens, it flows in an almost uninterrupted current from both nose and mouth, quickly producing syncope, or even convulsions and death. A certain quantity of blood is often swallowed, giving rise to hæmatemesis or to melæna. The uninterrupted duration of hæmoptysis is very variable, ranging from a few minutes to several days. A single attack sometimes occurs, but hæmoptysis is generally recurrent. The intervals between successive attacks vary from a few hours or days to months or years. Eichhorst affirms that malarial hæmoptysis recurs periodically at the time when a febrile paroxysm should be expected. A similar periodicity may obtain in amenorrhœal hæmoptysis. Hæmoptysis manifests a strong tendency to self-limitation, but it may, in exceptional cases, especially when dependent upon phthisis or on hæmophilia, recur so often as to cause death by exhaustion. Only in rare instances does the spitting of blood prove immediately fatal from rapid asthenia, or from asphyxia due to obstruction of the air passages.

The first sight of blood, especially in an initial hæmoptysis, engenders characteristic excitement and terror on the patient's part; but when a few safely surmounted paroxysms have demonstrated their comparative innocuousness, his mental equilibrium is often little disturbed by the onset of a new hemorrhage. In cases of moderate hæmoptysis the constitutional symptoms, aside from mental perturbation, betrayed by an anxious expression and by gentle tremor, are at first those of slight shock, *i.e.*, pallor, faintness or nausea, chilliness, and enfeeblement of the pulse. These symptoms are succeeded by congestion of the face and by augmented force and frequency of the heart's action, which phenomena gradually disappear after the cessation of the hemorrhage. In cases of more copious hæmoptysis the facial congestion gives place to returning pallor, the pulse becomes irregular and compressible, the respiration suspirious, the surface clammy, and the mind apathetic. Restlessness, tinnitus aurium, urgent thirst, falling temperature, nausea, muscæ volitantes, dimness of vision, increasing asthenia, transient syncope, and convulsive twitchings are symptoms which complete the clinical picture. In the worst cases of hæmoptysis the phenomena just enumerated appear in rapid succession, and death results either from syncope or from suffocation, due to obstruction of the air passages by fluid and coagulated blood. Hæmoptysis from hemorrhagic infarction generally ensues forty-eight hours, or even later, after the occurrence of pulmonary embolism, which, if the embolus be of septic character, is frequently announced by a chill. For the symptoms peculiar to hemorrhagic infarction, *vide* the article on *Lung, Infarction of the.* Hæmoptysis from the other predisposing and exciting causes described under the caption *Etiology,* as cancer, aneurisms, abscess, and gangrene, will, of course, be accompanied by the symptoms peculiar to these diseases. That pulmonary or bronchial hemorrhage and hæmoptysis are not convertible terms is shown by the fact that hemorrhages from the lungs sometimes occur without giving rise either to the prodromal or to the actual symptoms of hæmoptysis. These symptoms may be absent either if the quantity of extravasated blood be insignificant and undergo reabsorption, or if it be so large as to preclude the possibility of its expectoration by causing sudden death.

The *physical signs*, aside from those due to the diseases causing hæmoptysis, are usually unimportant. If the attack be slight, there may be no physical signs, or moist râles may show the presence of blood in the alveoli, bronchioles, and bronchi. No additional signs will be discovered, unless considerable consolidation has been produced by the accumulation of blood in the air passages and the interstitial pulmonary tissues, when dulness, and, provided that the bronchi be unobstructed, broncho-vesicular or bronchial respiration and increased vocal fremitus may be found. If the bronchi are completely or considerably obstructed, there will be diminution or absence of respiratory and of vocal signs.

TREATMENT.—The indications for the treatment of hæmoptysis are: first, the arrest of an actual attack; second, the prevention of its recurrence by treatment of the causative affections; and finally, the relief of its consecutive symptoms.

Energetic therapeutical measures are not indicated in mild attacks of hæmoptysis. Inasmuch as local depletion exerts a beneficial effect upon pulmonary congestion, which is the cause of most slight hemorrhages, it is advisable not to interfere with nature's efforts for the relief of excessive intravascular tension, but to second them by measures tending to the accomplishment of the same end. Whether, therefore, the congestion be active or passive, perfect quiescence, in a semi-recumbent position, should be strictly enjoined upon the patient. The statement that hæmoptysis is useful in relieving pulmonary congestion, and that its occurrence, given the usual pre-existing congestion, is desirable, should be confidently made, and is usually effective in quieting the patient's apprehensions. The sick-room must be kept cool, well ventilated, and free from all persons whose demeanor would tend to excite misgivings in the patient's mind. The bed-coverings are to be so light as not to compress the chest. The patient should be frequently reminded persistently to restrain his desire to cough. Mild revulsive measures, such as the application of mustard leaves, or of dry cups, to the exposed parts of the chest, and of stimulating pediluvia, are in order, as is derivation by means of a gentle saline purgative. If the pulmonary hyperæmia be active, cardiac sedatives may be employed, one of the best being the tincture of aconite, in two-drop doses, every twenty minutes, until a reduction in the force and frequency of the pulse, or tingling in the throat and finger-tips is observed. Should the hyperæmia be passive, as in uncompensated heart lesions, the tincture of digitalis, in ten-drop doses, should be administered, every hour, for the purpose of strengthening the heart's action. In cases of more profuse or protracted hæmoptysis the same rules regarding the patient's position and surroundings should be rigidly enforced, and more potent therapeutical measures adopted. If the hemorrhage be occasioned by excessive active hyperæmia, the patient being strong and plethoric, or by so great passive congestion as to threaten cardiac paralysis, venesection, to eight or ten ounces, affords prompt relief. This treatment is particularly adapted to the initial hæmoptysis of tuberculosis, and to pulmonary hemorrhage from rarefaction of the atmosphere, from the inhalation of irritating substances, and from violent physical exertions.

If the patient will not submit to the operation of phlebotomy, active congestion may be measurably controlled by a brisk saline purgative, by emetic doses of ipecac, as recommended by Trousseau and Graves, and recently advocated by Massina and Peter, but which must be avoided in hæmoptysis from cavities because of its tendency to prevent closure of bleeding vessels, or by the following therapeutic agents, which are useful in all varieties of profuse pulmonary hemorrhage. The most potent of these is cold, which is best applied by means of an ice-bag, of moderate weight, placed over the primary bronchi, or on that part of the chest to which the detection of râles points as the probable seat of hemorrhage. Small pieces of ice should be constantly dissolved in the mouth and swallowed. The best form of nourishment is cold milk, taken in quantities of eight ounces, at intervals of two or three hours. Physical examinations should be studiously avoided, as calculated to increase and to excite hæmoptysis, and as affording no important results. Ligation of the extremities, which is sometimes a very efficient hæmostatic measure, acts by retaining the venous blood in the limbs, while the arterial current is not arrested; but it must be cautiously employed, lest syncope or venous thrombosis be induced. These untoward results may be prevented by the simultaneous ligation of only two members, by leaving the ligatures in place for only a few minutes, consecutively, and by removing them so soon as hæmoptysis ceases. Ligation must, naturally, be undertaken only under the physician's immediate direction and supervision. Ergot is probably the most efficient hæmostatic remedy. It may be exhibited in the form of the fluid extract, in doses of one or two drachms, diluted with an ounce of water, every half-hour or hour, until the hemorrhage ceases or a decided diminution in the force and frequency of the pulse is observed. Should the stomach prove rebellious, half an ounce of the fluid extract, diluted with an equal quantity of lukewarm water, may be given by rectum, and repeated every hour until the physiological effects are produced. If it is desirable that the action of the drug be very speedily exerted, half a drachm of the fluid extract, or three grains of ergotin, dissolved in equal parts glycerin and water, should be subcutaneously administered, every half-hour, until the desired result is obtained. One grain of opium, or one-fourth grain of the sulphate of morphine, preferably in fluid form, must be immediately administered for the purpose of checking cough, and of inducing mental and physical quietude. The opiate should be repeated in doses of half the size mentioned, every two hours, until hemorrhage ceases or the physiological effects of the medicine are obtained. The most speedy and satisfactory method of administering the narcotic is by hypodermatic injection of the sulphate of morphine, particularly if simple emesis or hæmatemesis coexist with the hæmoptysis. Opiates are contraindicated when fatal accumulation of blood in the air passages is threatened. At such times expectoration should be encouraged and facilitated. Many authorities recommend that several teaspoonfuls of dry common salt be administered, if no other remedy be at hand, largely for the desirable moral effect resulting from medication in general, and partly on account of the unexplained but well-attested restraining effect of salt upon hæmoptysis. Inhalations of astringents, preferably of Monsel's solution, or of the *liquor ferri sesquichloridi*, diluted twenty-five times with water, and administered in the form of spray generated by an atomizer, are sometimes useful. The acetate of lead in two-grain doses, or gallic acid in twenty-grain doses, every three hours, is often administered internally, although the question of their value is still debatable. Bartholow extols the virtues of turpentine in hæmoptysis dependent upon hæmophilia and purpura.[3] It may be exhibited by mouth, in twenty-drop doses, in emulsion, or on sugar, or its vapor may be inhaled, for one-quarter hour, at intervals of two hours.

After-Treatment.—The objects of the after-treatment are the prevention of a recurrence of hæmoptysis, and the relief of its consecutive symptoms. The former indication is best fulfilled by the removal of predisposing morbid conditions, and by the avoidance of exciting causes. Many of the diseases predisposing to hæmoptysis, although, unfortunately, not amenable to curative measures, may be favorably influenced by judicious treatment. Pernicious malarial fever, of the hemorrhagic type, may be controlled by quinine and by other antiperiodics. Vicarious amenorrhœal hæmoptysis is to be combated by means tending to excite the normal menstrual flow, and scorbutic pulmonary hemorrhage by good food and vegetable acids. In cases of puerperal or marantic venous thrombosis, the utmost quietude should be enjoined, in order that pulmonary embolism, resulting in infarction and hæmoptysis, may be averted. Acute and chronic pulmonary inflammations must be subjected to appropriate treatment, and earnest efforts made to establish a compensation for existing organic cardiac diseases.

The exciting causes of hæmoptysis most easily avoided are those producing active pulmonary congestion, such as violent physical efforts, mental excitement, great rarefaction of the atmosphere and the inhalation of irritating vapors and gases. The chief direct sequelæ of hæmoptysis are bronchitis, bronchopneumonia, anæmia, and asthenia. The first and second are to be treated in accordance with generally recognized methods. The anæmia and asthenia are to be combated with tonics, preparations of iron, nourishing food, moderate and regular out-of-door exercise in pleasant weather, and, if extreme, by alcoholics rationally administered. If no other cause for a given attack of hæmoptysis can be discovered, it should be regarded as a probable initial symptom of pulmonary tuberculosis, and appropriate prophylactic measures should be immediately inaugurated.

William H. Flint.

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[1] Eichhorst: Handbuch d. spec. Path. u. Th., 1883, Bd. i., p. 490.

[2] J. Hughes Bennett: Reynolds' System of Medicine, vol. vii., p. 124, Philadelphia.

[3] Bartholow: Prac. of Med., p. 378, New York, 1880.

HÆMOSTATICS.—Hæmostatic drugs are such as are employed to control hemorrhage. When the hemorrhage occurs upon an exposed surface or from some accessible cavity, ordinary surgical measures are usually resorted to; but if the bleeding is not amenable to surgical treatment or if it occurs in some deeply seated organ, it becomes necessary to make use of astringent and styptic drugs. These may be made to act directly upon the part by applying them to the bleeding point, or their hæmostatic effect may be obtained by internal administration.

Whenever bleeding occurs the efforts of nature are directed toward a spontaneous cure. There is at once a contraction of the injured vessel, the torn coats of the artery retract, and the escaping blood is coagulated by contact with the surrounding tissues and upon exposure to the air. Should the loss of blood be severe, there is a weakening of the heart's action and a lessening of the blood pressure which greatly aid nature's efforts. These changes afford us an indication for treatment, and it is upon these principles that we select our remedies and endeavor to overcome the trouble.

The local application of extremes of heat and cold is a very common and a very effective means of controlling hemorrhage. Ice almost immediately contracts the vessels and blanches the part, and the employment of very hot water produces in a similar manner a spasmodic contraction of the vessels, and exercises a more marked effect in coagulating the blood. The custom of applying cold to the thorax with the object of checking hemorrhage in the lungs, or to the abdomen when the intestines are the seat of the trouble, is of doubtful value, unless the bleeding vessels are close to the surface. Many hold that it may do more harm than good by driving the blood from the surface to the organs beneath. The application of heat to the spine, although less common, is probably a more rational mode of treatment, the heat being applied over the ganglia which control the nerve supply of the part. Both heat and cold are most effective when brought in direct contact with the bleeding surface. Lumps of ice may be swallowed in hæmatemesis, or inserted into the rectum or vagina if the intestinal canal or the uterus is the part affected. In the same way the application of hot water to the open wound, or a hot injection in uterine hemorrhage is always of service and much more desirable than a cold application if there is much depression.

The local actions of hæmostatics differ somewhat. Some cause a firm clotting of the blood and are termed *styptics*, while others produce their effect by acting more directly upon the vessels. Of the styptics, the best known are the salts of iron, especially the subsulphate and persulphate, alum, acetate of lead, and tannic acid, all of which, although they exercise a constringing effect upon the vessels, act almost entirely by causing firm, adherent coagulation, not only of the blood but also of the adjacent albuminous tissues. By the time when this mass becomes detached the bleeding points are obliterated and a healthy surface remains. The hæmostatics which act more directly upon the vessels are alcohol, oil of turpentine, a weak solution of acetate of lead, antipyrin, and suprarenal extract. Suprarenal extract, as well as its derivative adrenalin, is the most typical of this class, and is probably the most valuable local hæmostatic that we possess. It produces a most powerful contraction of the vessels, and this persists for a long time. A solution of adrenalin, 1 in 10,000, renders the conjunctiva or any of the mucous membranes almost devoid of blood. It has been much employed to secure bloodless operations upon the nose and throat, as well as to check hemorrhage from any mucous surface.

The effect of the internal administration of hæmostatics is not so definite, nor is it readily explained, but clinical experience has taught us that several drugs may be depended upon for their hæmostatic action. Ergot, hydrastis, oil of turpentine, and aromatic sulphuric acid have all proved of service. They act upon the muscular elements of the arterial coats, causing a marked diminution in the calibre of the vessels; their effect is particularly marked on unstriped muscular tissue.

Tannic acid and vegetable preparations the astringency of which is due to tannin, are much employed in this way and have been thought to be decidedly beneficial. Tannin, however, is never absorbed into the blood except as gallic acid, which does not coagulate albumen and possesses very slight astringent properties. Except in hemorrhages from the stomach and bowels, tannic acid probably exerts no true hæmostatic effect. In such cases the drug probably produces an astringent effect because it is brought into direct contact with the affected parts. The same argument applies to the use of the mineral astringents, as alum and acetate of lead, for they both actively coagulate albumen and are thought not to pass beyond the mucous membrane of the intestines. Lead, however, enters the circulation as an albuminate and has a decided action in causing muscular contractions. Its effect upon renal hemorrhage is marked, but upon other organs its value is not so certain. The action of alum is less certain; it is absorbed as an albuminate and exercises an astringent effect when excreted by the kidneys and skin Its beneficial action in hemorrhage from other organs is doubtful.

In addition to the help obtainable from astringent remedies, it is possible to derive considerable assistance, in our efforts to control hemorrhage, from the use of sedatives and revulsants, which secure rest and lessen congestive states. Formerly these ends were attained by such drugs as tartar emetic, aconite, lobelia, and tobacco, and from a resort to venesection. Excepting in cerebral hemorrhage these remedies are now never resorted to. Instead, we place the patient in the most favorable position to secure bodily ease and functional rest of the implicated organ. If the lungs are affected, talking is forbidden; if the bleeding is from the digestive organs, food is restricted and rectal feeding substituted. Opium is always of the greatest service. In all forms of hemorrhage there are much restlessness and mental anguish, which interfere with all our efforts to effect a cure. Opium overcomes this disturbance by putting the muscles at rest and by calming the mental irritability. It also favors functional rest, not only of the organ affected, but also of the heart and circulation. It should be given freely (opium, from one to three grains; or morphine, half a grain). The only contraindications to its employment are cerebral hemorrhage, or those conditions which are characterized by extreme prostration and by the fact that the respiratory function is markedly weakened. Active purgation must not be neglected unless the bleeding is from the stomach or intestines. Such remedies as calomel, compound jalap powder, elaterium, and croton oil produce free evacuations, lessen all congestive states of the abdominal and thoracic organs, and reduce the general blood pressure. *Beaumont Small.*

HAIR DYES, INJURIOUS EFFECTS OF.—Although it is unquestionably true that the injurious effects of hair dyes have been grossly exaggerated, physicians should bear in mind the widespread habit of dyeing the hair, when called upon to treat certain obscure nervous symptoms and atypical lesions of the skin. This habit is not new, nor is it one of the passing fads of the day. It has been handed down to us from the most remote antiquity, and its votaries are to be found not only among the peoples of the East, but also among those of the western hemisphere. Thus, for example, we find that even the primitive American Indian found it expedient to dye his hair. Therefore, in view of the prevalence of the custom and when we consider the very few cases that are thereby injured, we are justified in coming to the conclusion that the evil effects have been grossly exaggerated.

The animal, vegetable, and mineral kingdoms have all been drawn upon to furnish their quota of substances for dyeing the hair and beard, until finally modern chemistry has been called upon to perfect the art.

It would be beyond the scope of this article to enter into a full description of the several hair dyes and the substances that have been employed for this purpose; it will suffice us to make a short summary of the ones most commonly used, such as pyrogallic acid, walnut hulls, indigo, henna, curcuma, hydrogen peroxide, potassium bichromate, silver nitrate, salts of lead, copper and iron, and last, but not least, chloride of paraphenylendiamin.

The injurious effects of hair dyes may be divided into three classes: First, injury to the hair; second, injury to the general system; third, local injury other than to the hair.

In the first class we would place hydrogen peroxide, which at the same time that it destroys the pigment extracts the fatty matter from the hair and thus destroys its vitality.

As an example of the second class the most common, most talked about is, of course, chronic saturnine intoxication with its attendant train of symptoms, wrist-drop, colics, etc.; this being due to the absorption of the salts of lead by the hairy scalp. At the present time we see little of this condition, but years ago it was relatively common.

In the third group we must place a number of trivial accidents, such as staining of the skin with the salts of such metals as iron, copper, manganese, silver, cadmium, etc.

The stains of iron, manganese, and cadmium may be removed by weak solutions of acids, while the brown stains of copper and the black stains of silver will be made to disappear by the application of cyanide of potassium and iodide of potassium.

Chromic acid or acid chromate of potassium will dye the hair yellow, but they are both caustic and poisonous.

The accidents brought about by pyrogallic acid and paraphenylendiamin chloride are more serious in character. Pyrogallic acid will sometimes produce, when used in sufficient strength anywhere about the face, a severe dermatitis with œdema, while if employed about the eyes it is apt to be followed by œdema of the eyelids, by conjunctivitis, and by extensive inflammation of the mucous lining of the nasal cavity.

Ever since the introduction of paraphenylendiamin chloride as a constituent of hair dyes many more instances of injuries due to hair dyes have been brought before the profession. The injuries that have sometimes followed the use of the drug include, among others, dermatitis of the hairy scalp, of the back of the neck, of the face, etc.—in fact, a dermatitis of that part of the skin that was brought in contact with the drug. In some cases the inflammation has extended to the neighboring parts, while Cathelmeau records a case in which the whole body was affected.

The character of the eruption varies from a slight erythema to a vesicular, papular, or pustular lesion; it may also be urticarial in character; œdema may be well marked, while pruritus may be intense. The eruption is sometimes accompanied by an elevation of temperature.

The *diagnosis* is sometimes attended with difficulty. Fournier gives as diagnostic points the suddenness of onset of symptoms, the rapidity of extension of the eruption, the enormous swelling of the eyelids. Sometimes the patients will aid us by connecting cause and effect. On the other hand, as in other conditions, too much reliance should not be placed on their statements, as they are apt to mislead us voluntarily or otherwise.

There is nothing special to offer in the way of *treatment;* these injuries should be treated exactly in the same manner as one would treat similar lesions in other conditions, provided that before the institution of any line of treatment the original cause be removed.

The *prognosis* is, as a rule, very good, although Brocq claims that in rare instances the condition proves rebellious to treatment. *N. J. Ponce de Léon.*

HAND.—Cresollius calls the hand "the minister of reason and wisdom." As the active servant of the brain, adjusted for the most delicate and varied uses, it has always been held in peculiar honor. The coat-of-arms of the surgeons' guild of the Middle Ages was a hand, with outspread fingers and an eye in their midst, typifying thus the noble art of chirurgie, which name was itself derived from *χείρ*, the hand, and *ἔργον*, work. Respect for this important member has even been carried so far that it has been supposed to contain a force within itself capable not only of intelligent action, but of transmission beyond the body. When we regard the high degree of muscular coördination which it possesses we readily see whence originates the first of these popular fancies, for the hand of the skilled musician, artist, or handicraftsman is a very different organ from that of the untrained and inexpert novice. The very word "handy" expresses this idea.

As to the second notion, it appears to be founded upon the extraordinary degree of tactile sensibility which the hand possesses. The laying on of hands has been a favorite method of healing from the very earliest historical period, and is still prevalent, not only where the royal touch is believed to be a sovereign remedy for "king's evil," but also among the so-called healing mediums.

The mesmeric passes were believed to be efficacious only when performed with the ends of the fingers, in order that the "force" might be drawn off into the patient's body. Von Reichenbach's patients saw flames of "od" force issuing from the ends of the fingers; many worthy people have no doubt that a nervous headache can be cured by some transfer of this force by means of passes over the brow of the sufferer; and we have lately had a revival of the old astrological theory of an "astral fluid" which is more transmissible from those with pointed fingers. Obscure nervous sensations felt in the fingers and along the nerve tracts are believed to be caused by this force or fluid. Owing probably to this superstitious reverence, we find that the physicians of the Middle Ages used the detached hand of a corpse for the scattering of tumors and the reduction of swellings.

The use of this strange remedy still survives. The author has recently found several authentic cases of such application. In one it was used for the cure of a white swelling, and in another for a protracted intermittent fever, a female homœopathic physician vouching for its efficacy. She explained this to the writer by stating that the "morbid processes going on in the dead hand attracted the disease and removed it" (!). Sometimes the virtue of the deceased is believed to have a marked influence. This was shown in the case of a well-known Catholic priest who died recently in Washington, and in that of a Carmelite nun in Baltimore. Many applications of the dead hand were made in both cases for the cure of the sick and afflicted, showing that the old belief is still active.

Another superstition which had a prominent place in the black art of the Middle Ages was that of the "hand of glory." This was a dead right hand of a murderer prepared with appropriate conjurations, in which was placed a magic candle made of murderer's fat and the hair of the dead. This was believed to prevent sleepers from awakening and to open locks and bars. As late as 1831, such a hand was left by thieves in a house in Loughcrew, Ireland. Thieves in Mexico use for a similar purpose the left hand and arm of a woman dying in her first childbed, and in 1875 a Mobile negro carried around with him the hand of his murdered victim to insure himself against detection.

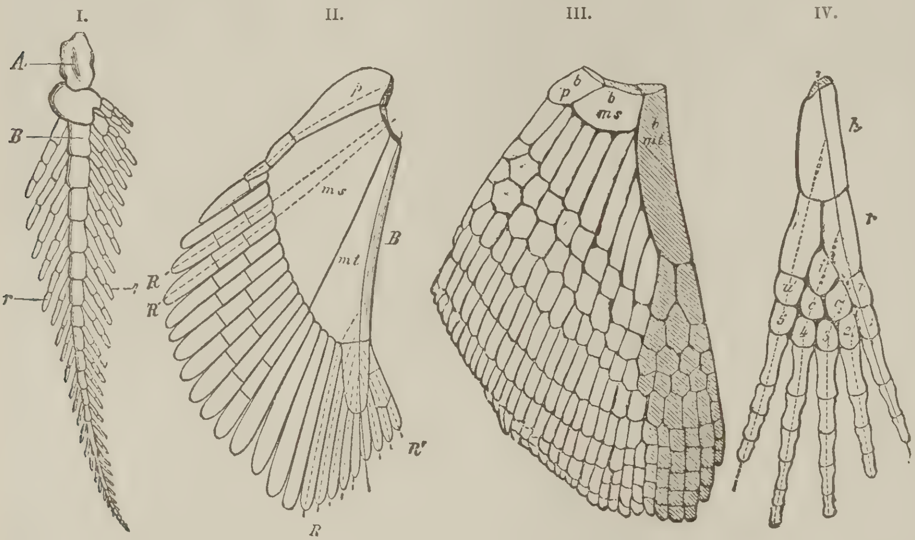

FIG. 2439.—Skeletons of the Thoracic Limb of Lower Vertebrates, showing the Gradual Development of the Hand.

Sir Charles Bell, the author of the celebrated "Bridgewater Treatise on the Hand,"[1] says: "We ought to define the hand as belonging exclusively to man, corresponding in sensibility and motion with that intelligence which converts the being who is weakest in natural defence, to a ruler over animate and inanimate nature." However flattering to our pride this statement of the great physiologist may be, modern investigation has shown that it is not anatomically correct, as there is nothing in the structure of the human hand that distinguishes it, except in degree, from that of anthropoid apes. Even Huxley's statement, that the apes do not possess an extensor of the metacarpal bone of the thumb, is open to question. Comparative anatomy shows us in fact that a general typical form for the thoracic limb and hand pervades the entire vertebrate series. This is especially marked in the mammalia, and in many cases the student of human anatomy has no difficulty in determining at once the different bones of the forefeet of an animal which he has never before seen. In one case within the author's experience, a professor of obstetrics who was not an anatomist, was obliged to examine a class in anatomy, and procured from the cabinet the skeleton of a bear's forepaw, which he passed around as belonging to the human skeleton. As the functions of the member vary, the different parts become reduced or increased either in size or in number, but a general plan pervades the whole, and the fin of a fish, the wing of a bird or a bat, the paw of an animal, are all constructed on a single type.

While the differences between the human hand and that of the higher apes are not essential, being only those of degree, yet the relative proportions of the different parts distinguish it markedly. The following table from Humphry shows the size of the hand and the foot relative to the stature taken as 100:

	Hand.	Foot.		Hand.	Foot.
Man	11.82	16.96	Chimpanzee	18.00	21.00
Gorilla	14.54	20.69	Orang	20.83	25.00

This superior length is due mainly to the metacarpal bones and phalanges.

With regard to the primitive origin of limbs two distinct views have been advanced by anatomists. According to the first the proximal part of the limb, which we are accustomed to call the shoulder or pelvic girdle (scapula and clavicle for the arm, innominate bone for the leg), arises from visceral arches of the vertebræ, and upon these radial bars of cartilage are set for the support of the fins. The pelvic girdle is thought to have become shifted backward in a marked degree. A complete homology, therefore, is believed to exist between the thoracic and the pelvic limbs.

The opposing view, which has recently been rapidly gaining ground, is that the shoulder and pelvic girdles are formed from coalesced vertebral elements. It is held that the most primitive form of limb is simply a lateral skin fold extending along the whole body, and that into this certain cartilaginous processes, or rays (actinophores of Ryder, pterygophores of Parker), extend. Each of these may bear several others extending radially through the fin. When necessary for more special forms of locomotion, the actinophores become united into solid bars constituting the shoulder and pelvic girdles, and the other skeletal elements are distally situated rays. Fig. 2439 shows various forms of fins found in primitive fishes; and it will be seen that there is a certain general resemblance to a hand with a large number of digits. According to this view there is no absolute homology between the thoracic and pelvic limbs, but only a homodynamy. Between fishes with fins and amphibia with feet there is a gap which has not yet been filled up by the discovery of intermediate forms, but it appears probable that the limb in its reduced state is the result of adaptation to walking instead of swimming.

In swimming it is necessary only to propel the body forward, in walking it must be also supported and raised; hence the necessity of the strong proximal bones and the bending at the shoulder, elbow, and wrist, and at the hip, knee, and ankle.

Fig. 2439, IV., shows how closely the plan of the hand and arm of an amphibian corresponds with that of man. From this point up through mammals there are many modifications, produced by the peculiar functions which the limbs are called upon to perform. When of use for prehension, digging, etc., the five-fingered type remains, and it is in fact the most persistent of all; but occasionally the occurrence of extra digits in the human species reminds us of a far-off ancestry, in whom the rays were more numerous. When the anterior limbs are used more for locomotion they become variously modified by stress and impact, and lose unnecessary digits. The reduction always takes place laterally. First the thumb becomes rudimentary or disappears, then the little finger, next the second finger, then the fourth, and so on. The discussion of the various causes for this is of extreme interest, but would exceed the proper limits of this article. The principal typical forms are shown in Fig. 2440.

Embryological evidence as to the development of the hand agrees, as far as it can at present be understood, with the facts observed in the animal series.

The first rudiment appears as a thickening and crescentic protuberance (see Fig. 2441, *A*), which grows laterally from the body wall. Further outgrowth may be arrested at this point, and in that case we have a child born with a hand springing directly from the shoulder, a species of monstrosity reminding one of the flipper of a seal, and hence called phocomelus. Normally, however, other segments are developed between the first bud and the body wall (Fig. 2441, *B*), and in these the bones of the arm develop. The formation of the fingers is first indicated by notches along the edge of the distal bud from which converging grooves run, indicating the future interdigital spaces (Fig. 2441, *C*). The first groove that appears is that between the thumb and the forefinger. The terminal phalanges soon become free, but the remaining portions of the fingers are united until the third month. If development is arrested here, we have the fingers remaining with a web between them, as in the amphibian paddle and in some quadrupeds. The thumbs become free first.

The varied structures of connective tissue, cartilage, bone, muscles, nerves, and vessels all develop gradually within this rudimentary bud, as they do in other parts of the body, by a differentiation of mesoblastic cells.

Some interesting problems are connected with the time and order of ossification of the various parts. The typical plan of the hand is shown in Fig. 2439, IV. In the wrist there are originally nine bones, which are arranged in two rows; those of the first are named systematically, the intermedium, between ulna and radius, ulnare, radiale, and correspond to the scaphoid, semilunar, and cuneiform bones of man. There is then a centrale (sometimes two, as shown in the figure) found in many apes and rodents, represented in the second month of fœtal life by a small independent cartilage; and then, in a second row, carpales I., II., III., IV., and V., each bearing a metacarpal bone. The first three of these correspond to the trapezium, trapezoid, and os magnum, the fourth and fifth uniting to form the unciform. The pisiform bone is generally held not to be an essential carpal element, but a sesamoid developed in the tendon of the extensor carpi ulnaris. A radial sesamoid occurs in some apes, and is occasionally found in man.

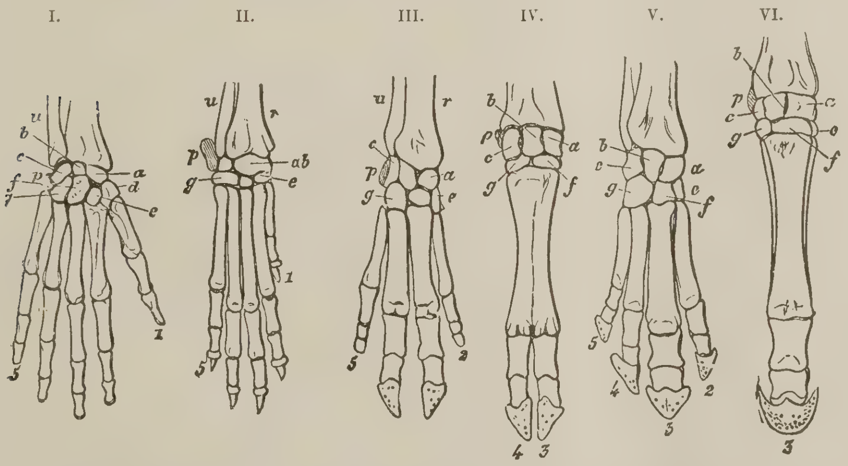

FIG. 2440.—Skeleton of Hand or Forefoot of Six Mammals. I., Man; II., dog; III., pig; IV., ox; V., tapir; VI., horse. *r*, Radius; *u*, ulna; *a*, scaphoid; *b*, semilunar; *c*, cuneiform; *d*, trapezium; *e*, trapezoid; *f*, os magnum; *g*, unciform; *p*, pisiform; 1, thumb; 2, index finger; 3, middle finger; 4, ring finger; 5, little finger. (Gegenbaur.)

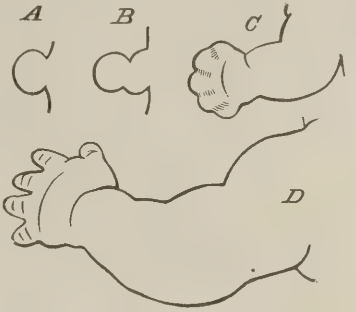

FIG. 2441.—Outlines of the Anterior Extremities of Human Embryos at Different Ages. (Allen Thompson, after His.) *A*, At four weeks; *B*, at five weeks; *C*, at seven week; *D*, at nine or ten weeks.

At birth all the carpal bones are cartilaginous. Ossification begins in the os magnum (first year), then follow the unciform, cuneiform, semilunar, scaphoid, trapezoid, and trapezium in about that order, and at intervals of from nine months to a year, so that the carpus proper is complete during the eighth year. The pisiform is somewhat later, not ossifying until from the tenth to the twelfth year.

The metacarpals follow the rule of long bones and ossify much earlier, commencing in the shaft at about the ninth week of fœtal life, an epiphysis remaining cartilaginous. In the metacarpal bone of the thumb this epiphysis is at the proximal end, but in the others it is distal. The epiphysis begins to ossify about the third year. The phalanges ossify in a similar manner, but the epiphyses in them are always at the proximal end. The agreement in ossification between the first metacarpal and the phalanges has given rise to much speculation. It has been supposed to indicate that the missing bone of the thumb is not a phalanx, but a true metacarpal. Sappey [2] believes the metacarpal epiphysis to be the metacarpal proper, the remaining part being a phalanx, which would make the thumb agree with the other digits as to the number of segments, as is the case with some other mammals, the sloth, for example. The metacarpal bone proper has, he supposes, atrophied so as to allow the thumb to be set farther back and obtain more perfect opposability. It appears doubtful whether we ought to accept this interpretation, as a proximal epiphysis occasionally appears in the second metacarpal, and some animals have both proximal and distal. It is suggested that too much weight should not be given by osteologists to epiphysial ossifications, as it appears probable that their presence or absence depends very much upon the activities of the animal in producing strains upon the skeletal elements.

The hand is regarded as divided topographically into three regions: the wrist, middle hand, and fingers—corresponding to the skeletal divisions of carpus, metacarpus, and phalanges.

REGION OF THE WRIST.—Externally this region is not very precisely defined. Its upper limits are generally regarded as marked in front by the upper transverse crease which runs across the forearm, always quite well marked even in extreme extension. Its lower limits are marked by another furrow, which curves around the base of the thumb. Behind, the marks of limitation are by no means as clear. Upon strongly extending the hand (dorsal flexion) there appear three or more furrows which correspond in a general way to the joints of the wrist, viz., the radio-carpal, medio-carpal, and carpo-metacarpal. Although described as such by Malgaigne, they are not practically good guides to the joints in question.

The muscles of the arm as they reach the wrist all become reduced to comparatively small tendons, which pass down over this region to be inserted below, the flexors lying on the anterior surface, and the extensors on the posterior and external. The wrist is, therefore, the narrowest part of the limb, and this affords an increased facility of motion to the hand as a whole. The bony parts are so arranged as to form an arch with the concavity forward, filled with the descending flexor tendons, and the great vessels and nerves. Under the skin of the anterior surface, which is smooth and without hairs, can easily be felt the prominent points of this arch, viz., on the radial side the tubercle of the scaphoid, on the ulnar the pisiform. These vary in prominence in different individuals. It is not uncommon for uninstructed persons to suppose that they have "a bone out," and unscrupulous quacks take advantage of this notion to work supposed cures.

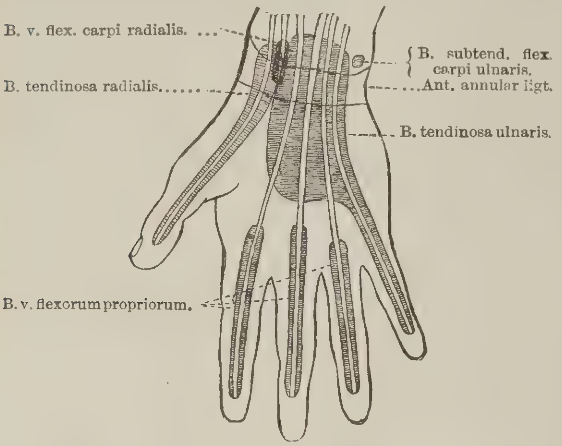
B. v. flex. carpi radialis.
B. subtend. flex. carpi ulnaris.
B. tendinosa radialis
Ant. annular ligt.
B. tendinosa ulnaris.
B. v. flexorum propriorum.

FIG. 2442.—Synovial Sheaths of the Palmar Surface of the Hand.

Upon flexing the hand a tendon starts up. This belongs to the palmaris longus, and in a lean wrist it can be plainly seen to spread out and become continuous with the palmar fascia. On the radial side of the palmaris tendon, and close to it, can be easily felt the tendon of the flexor carpi radialis. Behind and between these two lies the median nerve. When the superficialis volæ artery is large, it may be seen to pulsate where it lies alongside of the tubercle of the scaphoid. The radial artery usually does not appear here, having already passed outward under the extensor tendons of the thumb to reach the back of the hand. The point where the pulse is usually felt is not, strictly speaking, within the anatomical region of the wrist, but upon the lower end of the radius. It is admirably adapted for the purpose, as the artery here lies upon a bony bed, may be easily compressed, and is about to make a sudden and abrupt curve. Hence a careful palpation shows at once the amount of tension of the arterial wall. By extending the wrist, the artery may be slightly stretched and the structures above it rendered tense, so that it may be still more easily felt. Occasionally the superficialis volæ is given off higher than usual, and makes a secondary pulsation, the "*pulsus duplex*" of old authors (not the pulsus dicrotus). In this case it is easy to control it by pressing it against the scaphoid. On the ulnar side, the flexor carpi ulnaris tendon shows prominently in flexion of the wrist, as it passes down to its insertion in the pisiform bone, and externally to this the pulsation of the ulnar artery may be felt. The tendons of the flexors of the fingers lie deeper.

The skin upon the front of the wrist is firmly bound to the deeper structures by a very thin layer of subcutaneous tissue, and it is therefore difficult to make a flap from it in amputating the forearm. Flexion has produced a number of transverse markings. These are the *rasceta* of the chiromants, a word derived from the Arabic, signifying wrist. There are usually three of these, and they are not only prominent in all states of the hand, but are found in fœtal life. An attempt has therefore been made to give them significance as characteristic signs, but when we reflect that the hand of the fœtus is also movable and actively used, and that its condition is one of pronounced flexion of all the joints, it is not surprising, in view of the peculiar relations of the skin and subdermal tissue, that these as well as the lines of the palms should be formed.

Across the front of the wrist passes a thick band of fascia, called the anterior annular ligament. This being attached to the bony prominences on either side, confines the tendons in the deep carpal furrow or canal. The continual friction of the tendons along this furrow has caused extensive synovial sacs or sheaths to be formed. Occasionally but a single one occurs, enclosing all the tendons. The usual arrangement is, however, for two sheaths (Fig. 2442), one (*bursa tendinosa ulnaris*) surrounding the tendons of both superficial and deep flexors, the other (*bursa tendinosa radialis*) surrounding the tendon of the flexor longus pollicis. The ulnar sheath is almost always continuous with the sheath of the little finger, and amputation of that digit is therefore more apt to be followed by extensive suppuration than that of the index, middle, or ring fingers. These extensive synovial sacs are very troublesome when inflamed, as they may lead to extensive suppuration of the forearm, and, indeed, death has been known to follow. An amputation of the hand is much less serious.

Upon the dorsal surface of the wrist the skin is much more movable, somewhat hairy, and without prominent furrows. Under it may be seen two prominent, bony eminences—first, the round head of the ulna, second, the more obscure, pointed styloid process of the radius. From this latter, running toward the thumb, the tendon of the extensor of the metacarpal bone of the thumb appears on extension, and a short distance from it the extensor of the first phalanx. The triangular space between these has been called *la tabatière anatomique*, or anatomist's snuff-box, because it was formerly the custom, when snuff-taking was fashionable, to carry snuff to the nose in this little hollow (Hyrtl). By pressing deeply on this space, the beating of the radial artery may be felt as it passes under the tendons to reach the first metacarpal interspace, where it passes into the palm. It here rests on the scaphoid and trapezium. Over the back of the

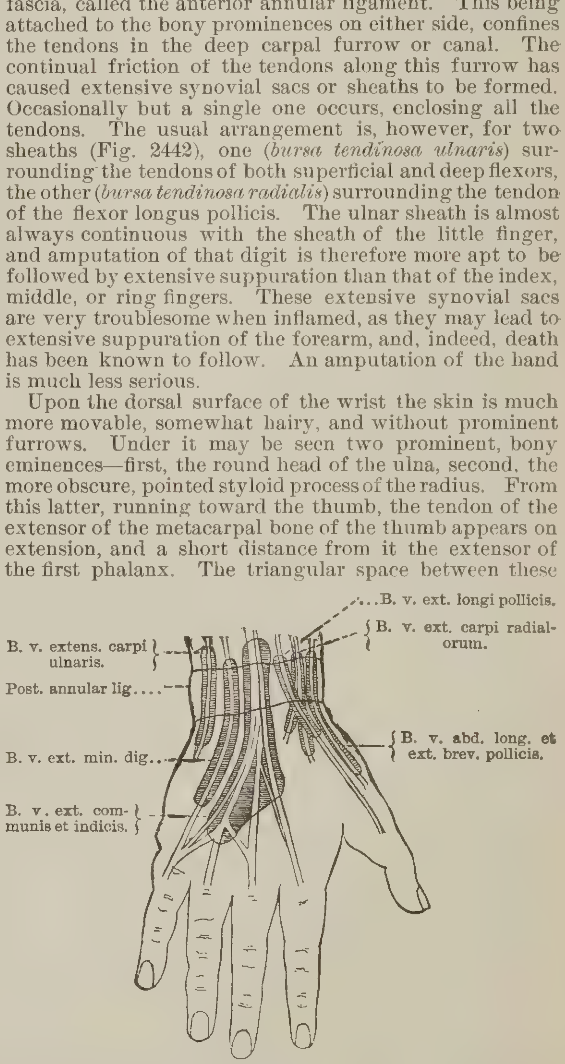
B. v. ext. longi pollicis.
B. v. extens. carpi ulnaris.
B. v. ext. carpi radialorum.
Post. annular lig.
B. v. abd. long. et ext. brev. pollicis.
B. v. ext. min. dig.
B. v. ext. communis et indicis.

FIG. 2443.—Synovial Sheaths of the Dorsal Surface of the Hand.

wrist and hand the tendons which come down from above, and are at first closely pressed together, begin to spread out to go to their respective insertions. These tendons are, from within outward, those of the extensor carpi ulnaris, extensor minimi digiti, extensor communis digitorum, extensor indicis, and the extensors of the thumb. These tendons are also confined by an annular ligament, and are furnished with synovial sheaths, as shown in Fig. 2443. The affection popularly known as weeping sinew (ganglion) is rather common in connection with these sheaths.

The small bones of the skeleton of the wrist are undoubtedly of considerable value in breaking and dispersing the shocks transmitted from the lower hand. The general plan of its construction has been already alluded to. We may consider the radius as bearing, first, the scaphoid (radiale), which in turn bears the trapezium and trapezoid (carpales I. and II.), the supporters of the first and second metacarpals; second, the semilunar (intermedium), which bears the os magnum (carpale III.) and the third metacarpal. The ulna does not directly join with the wrist, its carpal bone, the cuneiform (ulnare), being separated from it by the triangular fibrocartilage. This bears the unciform (carpales IV. and V. united) and the fourth and fifth metacarpals. The joints and ligaments of the wrist will be treated in a separate article.

Region of the Middle Hand.—The muscles which belong to the hand proper are arranged in two groups, one upon the radial side, making an elevation called the thenar eminence; another on the ulnar side, called by correspondence the hypothenar eminence. The upper part, where these two join, is called the ball of the hand, or by French anatomists *le talon de la main*. The central portion between the eminences is the hollow of the hand, and it can be contracted and deepened by the action of the muscles on either side. Because of this, it was called by the old anatomists *poculum Diogenis*, or Diogenes' cup, in allusion to the story that the cynic philosopher, on seeing a shepherd drink from his hand, vowed to henceforth use this, as the simplest possible utensil, instead of the rude wooden cup which he had heretofore deemed the acme of simplicity. Around this hollow are set the so-called "mounts" of chiromancy, governed, as is asserted, by the seven planets. The thenar eminence is styled the mount of Venus, and we may see a survival of the old notion in the fact that among the vulgar a titillation of this surface is believed to excite amatory passion.* It is possible that there may be an anatomical basis for this belief. An inspection of Fig. 2451 will show that the region in question lies in the boundary between the distribution of the ulnar and the median nerves, and is somewhat less fully supplied than are other parts of the hand. It is therefore, like other regions with the same character of nerve distribution, susceptible to that obscure form of nervous excitement called "tickling," which is known to cause a variety of reflex acts. We are as yet hardly sufficiently versed in the laws of transmission of impulses to decide absolutely that this may not have a reflex effect connected with the genital apparatus, especially if aided by an association of ideas

The lower part of the hypothenar eminence is called by palmisters the mount of the Moon, its upper the mount of Mars. At the root of the four fingers are the other mounts, which anatomical peculiarities are caused by the insertion into the roots of the fingers of the strong palmar fascia, by slips between which the tissues bulge. The mount of Jupiter belongs to the index, Saturn to the mediums, the Sun to the ring finger, and Mercury to the little finger. That this absurd farrago is not entirely obsolete the author has had ample evidence, as several intelligent people have assured him that they believe that these eminences have power to attract the seven different qualities of "astral fluid," and the doctrine has been fully set forth in more than one serious treatise within the last ten years.[3],[4],[5],[6],[7],[8]. Indeed, it would seem as if the advances of science within the present century, instead of extinguishing ignorant pretension, had caused pseudo-sciences to spring up by the score. Dazzled and bewildered by the evidences seen on every hand of the power of science, those untrained in the exact methods of scientific research are unable to distinguish between the true and the false, and a vast field is left open for charlatans and visionaries. The old astrologists believed not only that the hand was governed by the influence of the stars, but that certain signs were fixed upon it before birth, and became a basis from which to interpret the individual's character and constitution. Since this character and constitution have their limitations, signs for these also were found in the hand; and they further assumed that future events, such as sickness, death, and other matters of fortune or misfortune, could be foretold. There were many who went much farther than this into all the excesses of charlatanry.

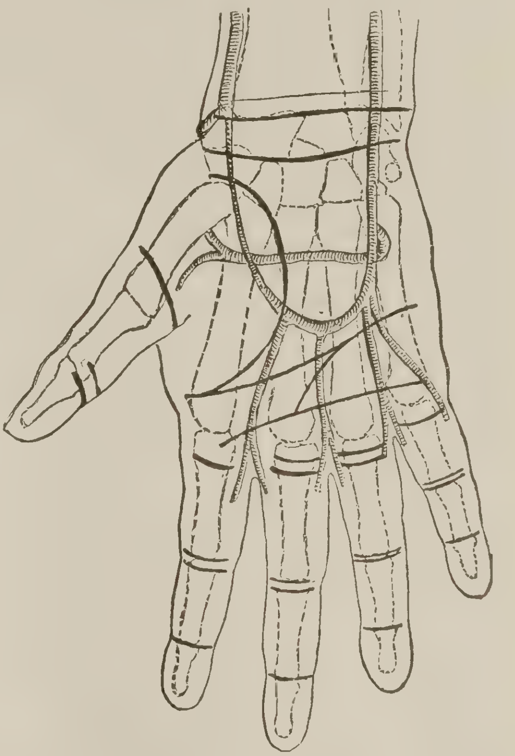

Fig. 2444.—Surface Markings on the Palm of the Hand. The thick black lines represent the chief creases on the skin. (Altered from Treves.)

The hand, being the servant of the mind, is modified and changed according to the use to which it is put; hence, say the palmisters, this organ is the appropriate index of character, and the lines of the hand, caused by the nervous influences actuating different muscles, and the tension and stress exerted on the skin, must be, if truly interpreted, a most significant guide. A little reflection will show that the modern disciples of palmistry have fallen into the same error as have the physiognomists and phrenologists, in that they expect to obtain exact and detailed particulars by examining physical characters which are highly generalized, being the result of a great number of separate physiological processes and acts.

Certain general notions as to bodily constitution, use, and adaptability can undoubtedly be made out upon the inspection of the hand; but there appears to be no warrant for any exact details. The principal lines are shown upon Fig. 2444.

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* Iago says of Desdemona: "Didst thou not see her paddle with the palm of his hand? Lechery by this hand, an index and obscure prologue to the history of lust and foul thoughts."

It will be seen that they form, rudely, the letter *M*. The one running around the ball of the thumb and marking off the thenar eminence was known to the old chiromants as the linea vitalis, or line of life. Measurements along this, made by describing arcs of circles from the several mounts, were believed to represent different periods of life, and any break in the line at the points where these crossed was said to indicate sickness or death at that period. This, gravely set forth in all recent works on palmistry, also appears in books of the sixteenth century, and probably farther back.[9] This fold, with another which occasionally occurs running from the wrist toward the finger, centrally through the palm, and called the saturnine line, or linea fortunæ, indicates to an anatomist only the action of the adductor pollicis in drawing the thumb over, and is deep or almost entirely absent as the thumb has great or little flexion. The statement is made by Langer,[10] that the saturnine line is not found in any but those of pure Caucasian race. As it is well marked in the chimpanzee, this seemed open to doubt, and the author has examined the hands of several negroes to ascertain if the statement had any foundation. In all those examined it showed with great clearness, even better than in whites.

From the radial border of the hand, near the upper end of the linea vitalis, arises the linea cephalica, or head line, which passes obliquely across the palm, disappearing near the ulnar edge. The value of this line to a surgeon is considerable, as, where it crosses the fourth metacarpal bone, it marks the superficial palmar arch (see Fig. 2444).

The arch may in some individuals be seen to pulsate strongly at this point. The commencement of the line indicates the metacarpo-phalangeal joint of the index finger. It appears to be caused by the flexion of the four fingers, and corresponds rather closely to the origin of the lumbricales from the flexor tendons.

Another line, not so extensive, is the linea mensalis, or heart line, which extends across under the mounts at the bases of the third, fourth, and fifth fingers. It is a little behind the metacarpo-phalangeal joints, and expresses flexion there of the three outer fingers, which usually act together. The name mensalis was given it because the names of the mounts were also names of months.

Besides the lines described, a number of others are mentioned by the chiromants, and in some hands there is a complete network. These might be of value for the purpose of proving personal identity in medico-legal cases. The occupation of the individual may occasion marks, callosities, and discolorations of the skin, alterations of the nails and hairs, formation of special bursæ, and even changes in the articulations, muscles, and bones, which are of importance in determining identity. The limits of this article will not permit of a full treatment of this subject, which has been very carefully examined by Vernois.[11] The shape of the hand may be permanently altered by the use of tools. The epidermis of the horny hand of a laborer may be so thick as to prevent the eruption of an abscess. The subcutaneous connective tissue of the palm is composed of short and thickly set fibrous bands, which firmly unite the skin with the deep fascia, forming partition walls of little chambers which contain fat. When the tissue is cut through, these little adipose masses, released from their confinement, extend beyond the edges of the wound. This arrangement secures a considerable degree of elasticity and protection. Abscesses do not usually point under thicker parts of the subcutaneous tissue, but seek the ball of the thumb and the hypothenar eminence.

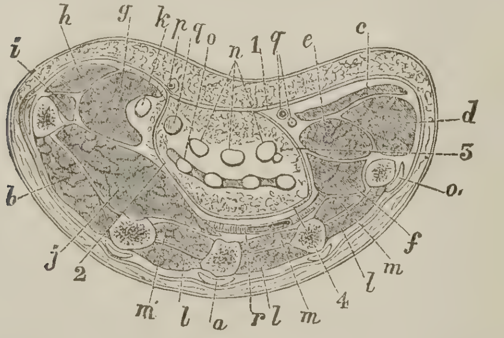

FIG. 2445.—Horizontal Section of the Hand through the Middle of the Thenar and Hypothenar Eminences. (Tillaux.) *a*, Metacarpal bone; *b*, first dorsal interosseus; *c*, palmaris brevis; *d*, abductor min. digiti; *e*, flexor brevis min. dig.; *f*, opponens min. dig.; *g*, flexor brevis poll.; *h*, abductor poll.; *i*, opponens poll.; *j*, adductor poll.; *k*, flexor long. poll.: *l*, dorsal interossei; *m*, palmar interossei; *n*, flexor sublimis: *o*, flexor profundus; *p*, superfic. volæ; *q*, median nerve, and (on inner side) ulnar artery and nerve; *r*, deep palmar arch; 1, palmar fascia; 2, outer septum; 3, inner septum: 4, deep fascia of palm.

The deep fascia is a strong and firm sheet, triangular in shape, the palmaris longus, its tensor, being inserted at the point of the triangle. Indeed, so continuously are the two united, that we may properly consider the fascia to be an expansion of the tendon. It occurs, however, when the muscle is wanting. Opposite the fingers it splits into four processes, which are inserted by these slips at the bases of the fingers and into the sheath of the flexor tendons and the first finger-joint. Acting through these slips, the palmaris acts therefore as a flexor of the fingers. A chronic shortening of this sheet is known as Dupuytren's contraction, and is always accompanied by a permanent bending of fingers. The little finger and ring finger are most affected; the thumb never, as it receives only a very insignificant slip of the palmar fascia.

A band of fascial fibres stretches across the roots of the fingers, and is known as the superficial transverse ligament. A thin fascia also separates the interosseous muscles from the rest of the palm. The metacarpal bones of all the fingers except the thumb are bound together at their lower ends by a strong strip called the transverse metacarpal ligament, and processes extend between this and the palmar fascia, making thus distinct chambers through which pass the flexor tendons as they go down to the fingers. It is through this passage that suppuration extends from the fingers into the palm.

Another series of orifices at the sides of the fingers permits the collateral vessels and nerves and the tendons of the lumbricales to reach the fingers.

The structures beneath the palmar fascia are contained in three compartments, which are separated by intermuscular septa; one (see Fig. 2445), external, separates the muscles of the thenar eminence and becomes continuous below with the sheath of the adductor pollicis, passing with it to be inserted into the third metacarpal; the other, internal, is attached to the anterior border of the fifth metacarpal, separating off the muscles of the hypothenar eminence. The middle compartment is the most important, as it contains, besides the flexor tendons and their accessory muscles, the vessels and nerves of the palm. The following table (on page 485) gives the principal facts regarding the muscles of the palm, as stated by the best authorities.

It should be noted that between the two heads of the flexor brevis pollicis the tendon of the long flexor of the thumb passes, lying in the groove of the trapezium. The deep head of this muscle (supplied by the ulnar nerve), as usually described, should rather be called a portion of the adductor pollicis, with which it is somewhat closely allied. The palmaris brevis probably, by its contraction, assists to protect the ulnar artery and nerve, which pass directly under it. When the fist is firmly clenched, this muscle assists in tightening the palmar aponeurosis, and its situation is marked by a little hollow on the ulnar side of the hand. It is not usually capable of independent action, but the author has found some persons who had the power to move it at will, thus wrinkling the skin. It appears to be a muscle derived from the panniculus carnosus, like the small muscles of the face.

	Origin.	Insertion.	Innervation.	Action.
THENAR MUSCLES.				
Abductor pollicis.......	Trapezium and annular ligament.	Base first phalanx of thumb.	Median...........	Abducts and rotates thumb and extends second phalanx.
Opponens pollicis......	Trapezium and annular ligament.	Metacarpale I. along whole length.	Median...........	Brings first metacarpal forward and rotates it inward.
Flexor brevis pollicis...	Trapezoid, os magnum, and metacarpales II. and III.	Base first palanx of thumb, with sesamoids.	Outer head median. Inner head ulnar.	Flexes and rotates first phalanx of thumb.
Adductor pollicis.......	Shaft of metacarpale III.	Base first phalanx of thumb.	Ulnar............	Adducts thumb.
HYPOTHENAR MUSCLES				
Abductor minimi digiti.	Pisiform and tendon flexor carpi ulnaris	Base first phalanx digit V., with slip to extensor tendon.	Ulnar............	Draws little finger away from others.
Opponens minimi digiti.	Annular ligament and unciform.	Ulnar border metacarpale V.	Ulnar............	Draws little finger forward, narrows hand, and deepens hollow.
Flexor brevis minimi digiti.	Annular ligament and unciform.	Base first phalanx digit V.	Ulnar.............	Keeps phalanx firmly down in grasping.
Palmaris brevis........	Palmar fascia and annular ligament.	Skin of inner border of palm.	Ulnar............	Draws up integument on inner side.
MEDIAN MUSCLES.				
Lumbricales...........	Radial sides of tendon of flexor profundus digitorum.	Radial sides of tendons of extensor communis digitorum and first phalanges.	First two by median, last two by ulnar.	Extensors of last two phalanges, flexors of first phalanges when these are semiflexed by the dorsal interossei. The first and second are abductors and rotators, the third and fourth adductors and rotators.
Palmar interossei......	Metacarpales II., IV., and V.	Bases of first plalanges digit. II., IV., and V.	Ulnar............	Extensors of last two phalanges, adductors and rotators, flexors of first phalanges.
Dorsal interossei........	Adjacent sides of metacarpals, more particularly upon those of the finger where insertion occurs.	Base of first phalanges digit. II., III., and IV., and to extensor tendon.	Ulnar............	Flexors and abductors of first phalanges, and in slight degree rotators. The third extends last two phalanges.

The lumbricales are so called because of their round, worm-like appearance. The old anatomists, because of their use in flexing and extending the fingers, called them fiducinales, or fiddler's muscles.

Duchenne[12] noticed that in persons who were suffering from lead paralysis, and had therefore no control over the extensor muscles supplied from the musculo-spiral nerve, there was still some power of extension in the second and third phalanges. The statement made in the table as to the action of the lumbricales is that of Adam,[13] founded upon observations made on the cadaver, and with electrical excitation with special instruments.

Fig. 2446 shows the manner of insertion of the lumbricales, as well as that of the interossei and the flexor tendons.

Besides the muscles mentioned in the table, the tendons shown in Fig. 2446 lie in the hollow of the hand. As they approach the fingers, the tendons of the superficial flexor lie immediately upon those of the deep, and in fact embrace them in a groove upon their under surface, this groove deepening until it at last becomes a slit through which the tendons of the deep flexor pass. It is therefore impossible to cut the tendons of the superficial flexor without at the same time cutting those of the deep flexor.

The back of the hand is convex, and shows plainly the metacarpal bones. When laid upon a flat surface, it is comparatively flat, but when the flexor tendons act they pull the bones together in such a way as to increase the convexity. The adaptability of this for the purpose of firmly seizing objects may be seen by reference to Fig. 2449. When the fingers are extended and spread apart, the extensor tendons shown in Fig. 2447 are well displayed.

Shallow furrows appear between the tendons, and at the lower part of the dorsum the heads of the metacarpal bones become prominent. At the base of the fingers the skin becomes thinned out into an interdigital web semilunar in shape. The web between the thumb and the index finger is thicker and more marked than elsewhere, because it contains in front the adductor of the thumb where it becomes free from the first dorsal interosseous muscle, which covers it in the upper part of the interspace. As the skin and fascia on the dorsal surface of the web are thinner than on the palmar, abscesses of the palm which reach the base of the fingers usually discharge behind.

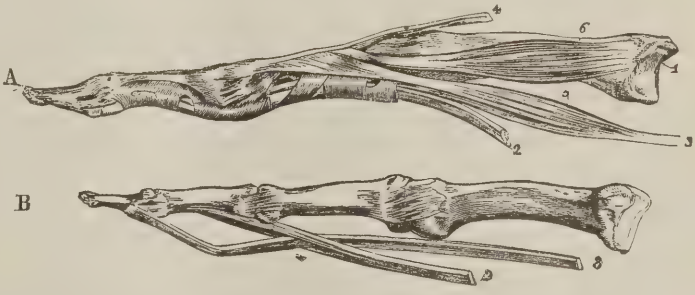

FIG. 2446.—Bones of Two Fingers, with the Insertions of the Tendons. (R. Quain.) In *A*, the tendons of the flexor muscles are bound to the bones by the fibrous sheath. In *B*, the sheath has been removed, as well as the vincula accessoria; 1, metacarpal bone; 2, tendon of the flexor sublimis: tendon of the flexor profundus; *, perforation of the sublimis by the profundus tendon; 4, tendon of the extensor communis digitorum; 5, lumbricalis muscle; 6, one of the interosseous muscles.

The skin of the dorsum is in many respects the opposite of that of the palm, being thin, easily movable, hairy, especially toward the ulnar side, and but slightly sensitive. Œdema is much more quickly shown here, the subcutaneous tissue being loose and numerous veins course through it. Some idea can be obtained of the tonicity of the vascular walls by noting their visibility through the skin. They vary much, however, in different individuals.

The deep fascia forms the sheaths of the tendons as they pass down. These tendons are arranged in two sets, which may be said to represent a superficial and a deep extensor similar to the arrangement of the flexors. To the superficial extensor belong the tendons of the extensor communis and the extensor minimi digiti, which pass down under the annular ligament almost vertically, diverging to their respective insertions after reaching the dorsum. The tendons of the communis, which go to the last three fingers, are united by oblique bands. This restricts the motion of the ring finger to a considerable degree, and it cannot be fully extended when the third or fifth digit is held firmly flexed. Subcutaneous section of these bands is sometimes resorted to for the purpose of giving pianists more independent movement of the ring finger. To the deep extensor set belong those muscles which, arising lower down upon the forearm, run somewhat obliquely across the others to be inserted into the index finger and the thumb. These are the three extensors of the thumb and the extensor indicis. Many varieties occur which confirm this view. In apes the extensor indicis also supplies the middle finger, and sometimes the ring finger as well. The extensor secundi internodii pollicis (which should be called extensor longus pollicis) also sends a tendon to the index, and sometimes to the medius. Similar variations occur in man. Koster[14] found the tendon of the indicis and the long extensor of the thumb united by a cross band like those which appear on the tendons of the common extensor.

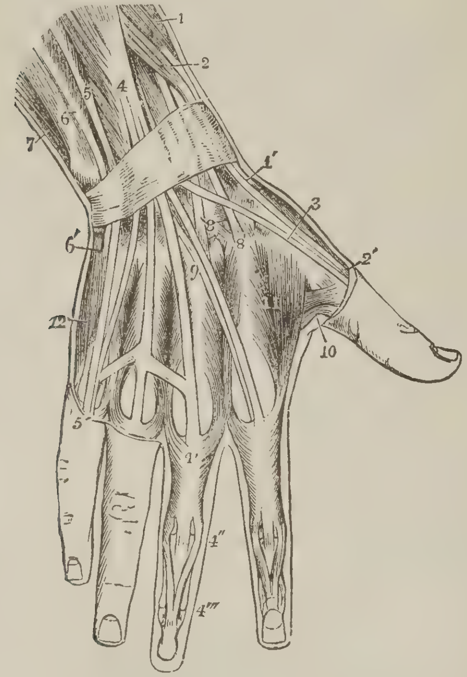

FIG. 2447.—Superficial Muscles and Tendons on the Back of the Wrist and Hand. (After Bourgery.) The posterior annular ligament of the wrist is represented. 1, Extensor ossis metacarpi pollicis; 1′, its insertion; 2, extensor primi internodii pollicis; 2′, its insertion; 3, tendon of extensor secundi internodii pollicis; 4, extensor communis digitorum; 4′, tendon of the middle finger receiving the insertion of the second and third dorsal interosseous muscles; 4″, division of the tendon into three portions, of which the median is inserted into the second phalanx, the two lateral passing on to be inserted at 4‴ into the terminal phalanx; 5, extensor minimi digiti; 5′, its junction with the slip of the common extensor; 6, placed on the lower end of the ulna, points to the extensor carpi ulnaris; 6′, insertion of this muscle into the base of the fifth metacarpal bone; 7, part of the flexor carpi ulnaris; 8, placed on the os magnum, points to the insertion of the extensor carpi radialis brevior; 8′, placed on the base of the second metacarpal bone, points to the insertion of the extensor carpi radialis longior; 9, tendon of extensor indicis; 10, small part of the adductor pollicis, and inner head of the flexor brevis pollicis; 11, first dorsal interosseous or abductor indicis; in the other three interosseous spaces are seen in succession, from the radial side inward, the insertion of the first palmar, second dorsal, third dorsal, second palmar, fourth dorsal, and third palmar interosseous muscles; 12, abductor minimi digiti.

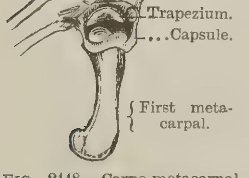

FIG. 2448.—Carpo-metacarpal Joint of the Thumb.

The bones of the middle hand are the five metacarpals, each concave toward the palm, and having a somewhat prismatic shaft with two enlarged extremities. Closely applied at the bases they spread along the shaft so that they never touch there, while again at the lower end they can be brought together. There is thus left room for the interossei muscles. The first metacarpal is an exception, as, in order to preserve the independence and opposability of the thumb, the base is set over and in front of the line of the others, and its distal end is not confined by ligaments. Since it is shaped more like a phalanx than like the others, anatomists have not failed to add this to other evidence which has been adduced to prove that the thumb has no true metacarpal. The joint by which it articulates with the trapezium is a saddle-joint, the movement being free in two planes, viz., that of flexion and extension, and that of adduction and abduction. It is not, however, limited to these, as circumduction can take place quite easily. There is no rotation. The capsule is thick and strong, and dislocation is very rare.

The situation of the joint is easily made out by running the finger upward along the shaft of the bone until it reaches the process at the base, immediately above which is the articulation. The process is made more prominent by strongly flexing and adducting the thumb, and the interarticular line can then be easily made out in most individuals. The other metacarpals are united to the wrist bones and to each other by articulations which are fixed by means of interosseous ligaments, which make their disarticulation very difficult. The fifth joint has the most movement.

The rounded lower ends of the metacarpals are of importance in forming an arch which strengthens the hand. For this reason they should be preserved in amputating the fingers, when it is possible to do so. The articular surfaces here are directed in such a manner as to have the planes of movement converge toward the middle of the hand. This greatly increases the power of grasp of the phalanges, as the tighter the fingers close the more strenuous becomes the lateral pressure. The convergence of the flexor tendons assists this. The extensor tendons pass over the most prominent part of the metacarpal heads behind. The third metacarpal, though not the longest, has its head more prominent, and is usually the one which receives injury from striking heavy blows.

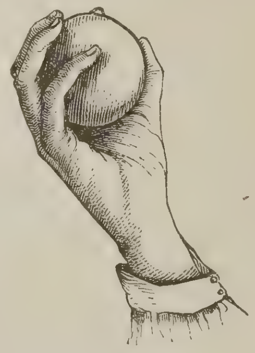

FIG. 2449.—The Length of the Fingers as Adapted in Grasping. (Humphry.)

THE FINGERS.—The anatomical names of the five digits or fingers are the pollex or thumb, indicis or index, medius or middle finger, annularis or ring finger, and auricularis or little finger, the latter presumably so called because of its use in cleaning the meatus auditorius. They are of notably different length, but somewhat nicely adjusted to the functions of grasping, as will be seen on holding a ball in the hand, as shown in Fig. 2449. The middle finger is the longest and has, therefore, the longest circumference to span, and the others are so adjusted, as to length, that they come very nearly to the same level at their tips. For this reason all tools which are to be grasped by the hand should have a swelling in the handle opposite the middle, so as to insure a good grip.

The usual arrangement as to length of the fingers is that in the extended hand the thumb does not quite reach the second phalanx of the index, the medius is longer than the annularis by half a nail, and the auricularis reaches only to the last phalanx. There is considerable variation in the length of the index. In about two-thirds of the cases (Mantegazza[15]) the index is shorter than the annularis, reaching only to the root of the nail of the medius. In others the two fingers are nearly of the same length, and rarely the index exceeds the annularis in length. Ecker[16] considers the shortness of the index to be a characteristic of apes, and thinks that when relatively longer it is an attribute of a higher form of hand. He finds it longer in women, who show in this, as in many anatomical features, signs of a purer morphological form. Carus[4] does not mention the length of the fingers, but figures what he calls, after d'Arpentigny,[3] the idealistic hand (seelische Hand, main psychique), which shows a long index. It is noticed by Hyrtl[17] that the apparent length of the ring and index fingers may be influenced by the posture of the hand. If the hand is laid flat, so that the axis of the medius corresponds with that of the entire arm, the index usually appears a little shorter than the ring, but abduct the hand, and the ring finger will appear a whole nail's length longer. Grüning[18] has recently given the results of two hundred observations very carefully taken. He finds that the ring finger is usually the longer, yet the reverse is not uncommon, and more frequent in females. In the foot the second toe is usually the longest, but a greater length of the big toe is not rare, also more frequent in females. This lends some support to the theory that the foot has no digit homologous with the thumb.

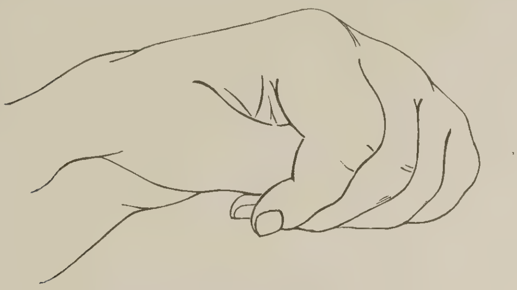

FIG. 2450.—The Convulsive Hand. (Warner.[21])

The general relation of the middle finger to the rest of the hand is expressed by Langer[10] as follows: If a measurement be taken from the os magnum to the end of the finger, the various parts, as measured from the angles at the joints made by flexion, will be in the proportion of 8 : 5 : 3 : 2, that is to say, the middle hand is as long as the three other portions, and the basal phalanx is as long as the middle and ungual together. The length of the entire hand has been used by artists as a canon of proportion for the whole body, being set at one-ninth of the whole height. The Egyptian canon seems to have been based upon the length of the index, which was reckoned as one-nineteenth of the height. Many measures used as rough estimates are taken from the hand: the length of the middle finger from knuckle to point is reckoned as one-eighth of a yard, and from the tip of the thumb nail to the second joint as about half of that, and is called one nail. The breadth of the hand is used as a measure for horses, and is reckoned at four inches. The breadth of the thumb is the pouce or inch of the old French measures. Of course all these are liable to vary because of individual peculiarity.[19]

It should be noted that the proportions of the hand to the entire height are attained very early, at least by the fifth year (Quetelet[20]). The member appears to have the same early physical development that the brain has, and the hand of the new-born child is structurally that of the adult, differing only in size.

The thumb has from very early times held the place of honor among the digits, as the loss of it deprived the hand of much of its power. It is especially by the superiority of the thumb that man's hand is distinguished from that of the higher apes. There are no less than eight muscles attached to it, and this gives a freedom and variety of motion which is not possessed by any other digit. To cut off the thumb was an old method of disabling an enemy, by preventing him from properly using his weapons, and soldiers sometimes resorted to this mutilation to exempt themselves from military duty —as those of our own time have been known to amputate the terminal phalanx of the index to unfit themselves for pulling the trigger of a gun. It is from this custom that the word poltroon is said to have arisen, being a corruption of *pollice truncus.* The palmisters exalt the thumb far above the other digits. D'Arpentigny says: "*l'Animal supérieur est dans la main, l'homme est dans le pouce.*"

The Esquimaux tradition is that woman was originally formed from the thumb of man. The thumb was used by the spectators of Roman gladiatorial combats to indicate whether the conquered party should die or live. In La Vendée a large thumb indicates a predilection for the black art, and to bite the thumb is a grave insult in Scotland and Italy.*

The unusual strength of the muscles which are attached to the thumb, making it an efficient portion of a pair of forceps when applied to the other fingers, leads also to its being affected by convulsive action. In almost all cases of this kind the thumb is firmly clenched and drawn into the palm (see Fig. 2450). This may be of service as a medico-legal sign, as it is almost always found in those who have died a violent death, and consequently suffered spasmodic contraction of the muscles during the last agony.

The index or pointing finger has been called the gynæcologist's eye. It is somewhat more sensitive to tactile impression than the others, and, being supplied with special muscles, it is particularly serviceable as the antagonist of the thumb. It is always best to preserve this finger and the thumb, if possible, in injuries to the hand, as by themselves they make quite a serviceable organ.

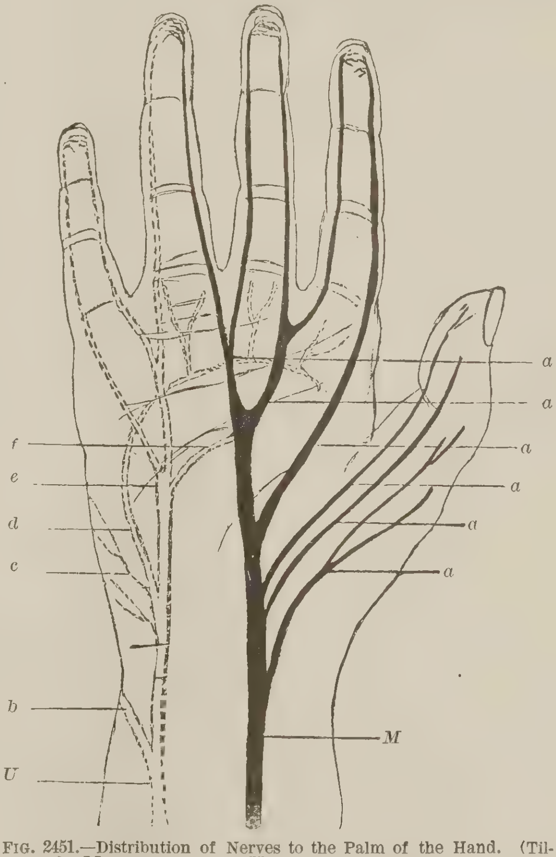

FIG. 2451.—Distribution of Nerves to the Palm of the Hand. (Tillaux.) *M*, Median nerve; *U*, ulnar nerve; *a*, *a*, *a*, *a*, *a*, *a*, collateral branches of the median nerve; *b*, dorsal branch of the ulnar nerve; *c*, muscular branches; *d*, superficial branch; *e*, deep branch; *f*, anastomotic branch.

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* Vide Romeo and Juliet, Act I., sc. 2. "I will bite my thumb at them, which is a disgrace if they bear it."

The ring finger, or annularis, is so called from the fact that it has been customary, since the time of the Romans, to carry rings upon it. This has been said to originate in the fact that they supposed it to be especially connected with the heart, either because it is supplied by two nerves (see Fig. 2451), or more probably because the vena salvatella runs prominently from it up the arm. Owing to the connection of the tendons this finger is somewhat protected by those beside it, and consequently is less liable than the others to injury, and this affords ample reason why it, as well as the left hand, should be chosen to wear the ring. The old anatomists called it the digitus medicus, because they were accustomed to mix medicines with it.

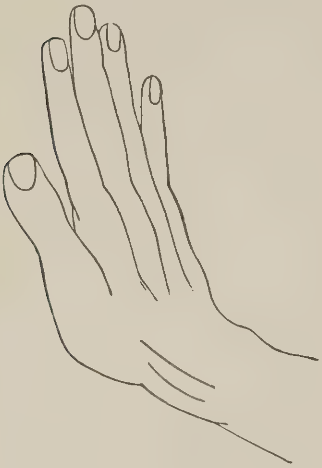

FIG. 2452. — The Hand in Fright. (Warner.)

Upon the palmar face of the fingers are seen certain transverse furrows, well marked. These are important guides to the joints and should be well noted (see Fig. 2444). They are not correctly given in any of the books on palmistry which the author has consulted, which shows that in point of accuracy their "science" leaves something to be desired. The folds nearest the palm are single for the index and little fingers, double for the others. They do not correspond exactly to the metacarpo-phalangeal joints, but are three-fourths of an inch below. The middle folds are double and exactly opposite the joints, the lower folds are all single and a trifle above the joints. Upon the thumb there are also three folds, the upper and lower folds correspond to the joints very nearly, the middle one having no topographical significance. The skin on the fingers is remarkably rich in papillæ; the number of these containing nerves increases as we proceed toward the finger tips. These papillæ, both on the fingers and palm, are arranged in lines forming characteristic curvilinear ridges. Upon the eminences formed by the pulps of the fingers and the eminences of the palm these are arranged in elliptical or spiral patterns, and it has been seriously proposed to use these as a means of identifying individuals. In certain cases they have been of service. Faulds[22] mentions that by means of finger marks upon a greasy glass it was ascertained who, among a number of servants, had been drinking some rectified spirit; and another case, in which a criminal was detected by an impression of sooty finger marks on a white wall. He considers that the Mongolian races have a special and characteristic pattern. The city authorities of San Francisco recently considered the propriety of registering all the Chinese who arrived at the port by taking an impression of the thumb. It is said that the legal expression "my hand and seal," arose from the custom of sealing papers with the thumb.

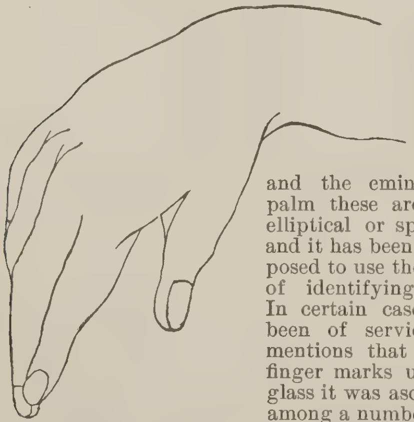

FIG. 2453.—The Feeble Hand. (Warner.)

Beneath the skin the subcutaneous tissue is like that of the palm—a series of little cushions of fat. On the last phalanx this is called the pulp of the finger. Still deeper is found the canal for the flexor tendons. The fibres of this sheath are less thick opposite the joints, so as not to impede flexion. They are continuous above with the palmar fascia. The canal contains in the thumb only the tendon of the long flexor, in the other fingers the tendons of the superficial and deep flexors. They are united to the sheath by small bands termed retinacula. Opposite the first phalanx the flexor sublimis splits and the two halves fold around the deep flexor, again uniting behind it by their margins. They then separate and are inserted into the second phalanx (see Fig. 2446, *B*). The deep flexor is inserted into the terminal phalanges. Some persons have power to use it independently.

On the dorsal surface of the fingers the skin forms elliptical folds at the articulations of the first and second phalanges, and simply a few transverse folds at the articulations of the second and third. Under the skin the extensor tendons form a broad aponeurotic sheet into which the expanded tendons of the lumbricales and interossei are inserted. This sheet terminates with the insertion of the extensor into the last phalanx.

The nails which terminate the digits are, as is well known, really epidermal elements. They are found in the embryo at about the third month of pregnancy. Their growth is always from the root, and the rate at which they grow can frequently be noted by the spots which occur upon them, and thus a general notion may be obtained of the vigor of the processes of nutrition.

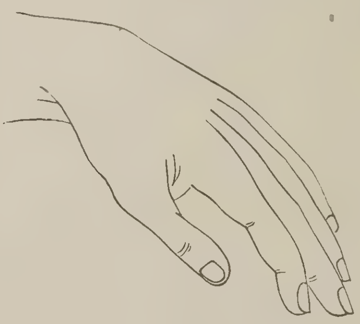

FIG. 2454.—The Tonic Hand. (Warner.)

The joints of the fingers have a general resemblance to each other, the metacarpo-phalangeal being merely a little broader. The ends of the phalanges broaden out somewhat at their extremities, and when the body becomes emaciated, as in a wasting disease, these ends become very prominent, and the disorder known as clubbed fingers results. At the metacarpo-phalangeal joint of the thumb there are two sesamoid bones, which are believed to be one of the causes of the difficulty of reducing a dislocation at that joint. Similar structures, usually cartilaginous, however, are found on the palmar surfaces of each of the phalangeal joints. In negroes, or in those laborers who use the hands much for heavy work, they may all be ossified, as they are in the forefoot of a bear. The articulations are all imperfect hinge joints, having lateral ligaments and a thickening of the capsule on the palmar surface. It should be remembered that the articular line is always found beyond the angle formed by the flexion of the phalanges.

The nerves of the hand are three in number. Their distribution to the palmar surface is shown in Fig. 2451, and the muscles they supply are mentioned in the table on page 485.

To those mentioned there should be added those which come down from above. Of these the flexors are supplied by the median and ulnar, the extensors by the radial. The ulnar supplies the flexor carpi ulnaris and the principal part of the deep flexor, leaving to the median that portion which goes to the index finger, which might, therefore, properly be classed as a separate muscle.

After section of the median nerve a considerable movement is left to the fingers, pronation being effected by the shoulder muscles acting on the arm, flexion of the wrist by the flexor carpi ulnaris, the first phalanges flexed by the interossei, the others by the deep flexor. The thumb suffers most, and we may, accordingly, say that the median nerve especially presides over the movements of that digit.

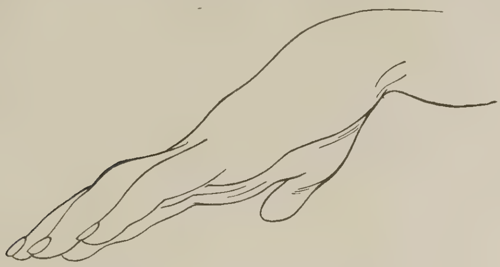

FIG. 2455.—The Nervous Hand. (Warner.)

In the same way as motility is not entirely lost, so also is sensibility retained to some extent. The anæsthesia does not correspond with the distribution of the nerve. The reason for this is believed to be found in the collateral branches which run from the ulnar to anastomose with the median. There is no doubt that the anæsthesia after section continues to grow less, and it has been suggested that when certain parts are disabled, other nerves may send out filaments from the fine plexus into which the nerves break up before going to supply the papillæ, in order to supply the need.

The correlative action of the muscles and nerves has a very marked result upon what may be called the physiognomy of the hand. Warner[21] has carefully studied this subject, and describes, among others, the following types, which relate to the expression of the emotions: The convulsive hand (Fig. 2450), in which the thumb is forcibly and violently adducted, the fingers are pressed closely together and semiflexed on the thumb, the hand assuming a conical shape. The opposite of this is the hand in fright (Fig. 2452), the phalanges and the wrist being extended. The whole attitude is that of repelling an abhorrent object. In pure horror, not accompanied by fear, the hands are thrown widely back, the arms uplifted, the fingers open. A passenger upon a train that ran over a man told me her first intimation of an accident was seeing through the window a person assume this attitude as the train shot past. The convulsive wringing of the hands is an expression of quite an opposite order, indicating intense and continued painful emotion, and instead of the hand-washing motion performed by tragic actors, is, when genuine, a passing of one hand down the other, with a convulsive twist at the ends of the fingers.

The feeble hand (Fig. 2453) is indicated by a dropping of the thumb and a bending of the phalanges.

The tonic hand in rest (Fig. 2454) is like this, but differs in the degree of the action. The nervous hand (Fig. 2455) has the wrist slightly bent, and the metacarpophalangeal joints hyperextended, and the first and third internodes slightly flexed.

The energetic hand (Fig. 2456) is the opposite of this, the wrist being extended and the small joints in flexion.

The vessels of the hand have recently been the subject of careful study by Bourceret,[24] and he has arrived at some conclusions which seem important and new. By a very ingenious process, and using a series of injections, he has been able not only to fill the entire arterial and capillary system, but the venous system as well, injecting from the heart outward, notwithstanding the valves.

The arrangement of the arteries has already been alluded to. The radial and ulnar form, as shown in Fig. 2444, two arterial arcades known as the superficial and deep palmar arches, the first of them being made by the radial and the deep branch of the ulnar. To these may be added a third arch over the back of the wrist, formed by collateral branches of the two trunks. From these arches pass branches which supply the fingers, being of considerable size throughout their length, even to the last phalanges, and not accompanied by venæ comites. The object of this excessive vascular supply is not only the nutrition of the fingers, but also to maintain the bodily warmth there. They communicate by two sets of capillaries, one small and intended for nutrition only, the other large and intended for increasing the heat. These capillaries are arranged in very complicated tortuosities, like little balls of tangled thread. They open immediately into the veins, which are also remarkable for their flexuosities. Any consideration of the hand would be incomplete without some remark concerning the separate use of the two hands. Right-handedness, or rather right-sidedness, for the matter is not by any means confined to the hand, is the rule among all races of men, and some traces of it may be seen in the animal creation. The elephant, for example, is said to use the right tusk more than the left, and this is accordingly called the servant tusk.[25] Left-handedness is the exception, occurring in about nine per cent. of individuals. Many attempts have been made to explain this, and Franklin's[26] plea for the left hand, and Charles Reade's essay[27] upon the injury mankind inflicts upon itself by the continuous use of the right, are well-known curiosities of literature. It appears, however, that there is reason to suppose that we have, in dextral preference, merely a further differentiation like that which has resulted in the development of the feet and hands from four originally similar organs. The left hemisphere of the brain appears to be assuming control of the more complicated motor functions performed by the right side of the body, while the right hemisphere attends more especially to the nutritive functions through the sympathetic system. It is noted that the senses of temperature and of weight are usually more acute in the left hand. Perhaps this is in some degree due to its less frequent use. Granting this, we have to search for the origination of the tendency. Hyrtl[17] supposes it to arise from the fact that the innominate artery carries more blood to the right side. Dwight and others[28,29,30] think it depends upon the situation of the left carotid at the top of the arch, surmising that it receives a swifter current of blood, which goes to the left brain, controlling the left side. Blumenbach supposed that it was due to a deviation of the innominate artery to the left. Breschet thought that there was an innate tendency to a predominance of nutrition on the right side in fœtal life. The right side of the spine develops first and so throws the heart to the left. Comte[31] suggests that it is due to the fact that the fœtus in utero lies usually on the left side, owing to the obliquity of the pelvis, and that this occasions a precocity of development of the right side. The percentage of left-handed persons is about that of presentations where the fœtus lies on its right side.

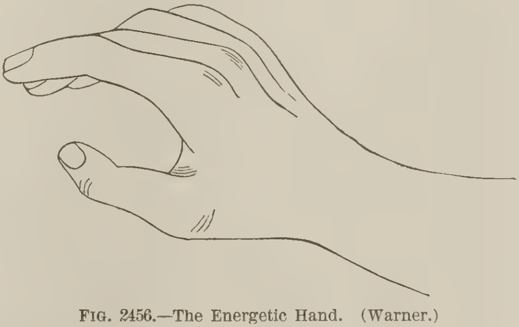

FIG. 2456.—The Energetic Hand. (Warner.)

An ingenious explanation is offered by Buchanan,[32] who holds that the centre of gravity lies on the right side owing to the weight of the liver, and that this causes a greater development of the muscles there. It is possible that several of these causes may have had an effect upon the matter. An efficient cause may be found in the situation of the heart upon the left side. A savage soon learns that his enemy is vulnerable there, and takes pains to protect himself by withdrawing the left side and using the weapon with the right. The constant persistence of this use of the right arm as the weapon-bearing member has probably resulted in organic dextral preference, and left-handedness may be considered an atavism.

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HANDS AND FINGERS, DISEASES AND DEFORMITIES OF.—The hand is such an important and essential factor in the practical economy of life that the pathological conditions to which it is subject and which tend to impair its usefulness form an important field of medical science and practice. It is a topographical region so well marked off, and is subject to such special pathologic and etiologic factors, that the morbid conditions which affect it make up quite a distinctive and well-marked group of diseases. The diseases to which the hands and fingers are subject comprise a considerable variety of conditions, diverse in their nature and cause, with the only element of unity resting in their common site. A comparative consideration of all these various conditions may prove of advantage in questions of differential diagnosis; and some of the rarer affections may be pointed out which from not being often observed may prove puzzling when cases are met with.

Special Pathological and Etiological Factors.—The hand exhibits a number of characteristics that exert special influences in determining and bringing about the morbid conditions to which it is subject.

Among these special causative factors is the peculiar anatomical construction of the hand. The hand is essentially a delicate motor mechanism and arrangement of joints, ligaments, tendons, and the like, all so nicely adjusted that slight impediments (as in trigger finger) may result in material deformity or impairment of function.

Another condition that subjects the hand to certain forms of disease is its use and its exposed situation, rendering it especially liable to mechanical, traumatic, atmospheric, irritative, and other influences. The constant usage of the hand incident to various occupations produces corresponding reactions and morphological and pathological consequences, as in writer's cramp and the stiffening and hardening effects of manual labor. The hand is much exposed to injuries, mechanical, chemical, thermic, while its being habitually uncovered by clothing and thus exposed to meteorological and other irritative influences makes it subject to certain skin affections.

The situation of the hand at a distance from the circulatory centres is another factor that gives rise to various pathological conditions. The great distance of the hand from the heart causes a relative weakness of the circulation in this member, which results in the occurrence of circulatory disturbances like stasis, clubbed fingers, œdema, and Raynaud's disease in this locality.

Its distant situation also renders the hand liable to suffer consequences of injuries or lesions primarily located at points between it and the trunk or the bodily centres. The motor mechanism of the hand is located chiefly in the forearm, while the vascular and nervous trunks that supply it course along the entire upper extremity, so that diseases or injuries of any of these structures in any part of their course may result in morbid conditions seated in the hand.

Other conditions there are which affect this region exclusively or peculiarly, for physiological reasons that, though obscure or unknown to us, are yet real and operative. These may be regarded as idiopathic pathological factors and diseases of the hand, exemplified by Dupuytren's contraction.

Classification.—The affections of the hand and fingers include those that are peculiar to or affect this region exclusively; those that may occur elsewhere, but show a predilection for, or exhibit special features or modifications in, this locality; those conditions affecting the hands equally and indifferently with other parts of the body; and the manifestations, exhibited by the hand, of general disease. The conditions of most pertinence to the present subject are those more or less peculiar to the hand or those that exhibit special features in this locality.

It is not easy to formulate a completely satisfactory and logical classification of all the affections of the hand and fingers on any uniform basis. There are several grounds on which classification may be based, but no one of them alone in the present state of our knowledge is sufficient to afford a practical and adequate classification.

From one standpoint a division can be made, with reference to the manner in which the etiological factors are brought to bear, into conditions arising: from local causes, either external or internal; from extension (by continuity or contiguity) from neighboring structures that are affected; from causes (nutritive, toxic, metastatic) brought to bear through the medium of the circulation; or from impressions derived from the nervous system. The difficulty with a strictly etiological classification consists in the fact that identical pathological conditions may result from very different causes.

Another basis of classification of diseases of the hand rests upon their pathological nature, as parasitic and infectious conditions, neoplasms, traumatisms, senile conditions, etc. The adequacy of such a classification is impaired by our ignorance of the essential pathological nature of many obscure affections. Another division is to be found in the different regions, tissues, and anatomical structures involved, as the affections of the nails, the fascias, the skin, the ligaments, the joints, etc. This division applies well in many cases, but in those conditions in which more than one set of tissues or structures is involved a satisfactory arrangement would be difficult.

The considerations mentioned enable us to mark off some well-defined groups of diseases of the hand, while other morbid conditions are not easily susceptible of classification. The following arrangement of the diseases and deformities of the hand and fingers will be followed in this article:

- Congenital and developmental anomalies:
    - Acheiria.
    - Ectrodactylism.
    - Hypophalangism.
    - Polycheiria.
    - Polydactylism.
    - Polyphalangism.
- Syndactylism.
- Cleft hand.
- Congenital constrictions.
- Deflections of the hand and fingers.
    - Club-hand.
    - Congenital deflections of the fingers.
    - Lateral deflections of the fingers.
    - Backward deflections of the fingers.
- Microcheiria and microdactylism.
- Hypertrophy of hand and fingers—cheiromegaly and dactylomegaly.
- Neoplasms.
- Cysts.
- Traumatisms and injuries.
- Inflammatory conditions.
- Infectious and parasitic conditions.
    - Suppurative and allied conditions.
    - Tuberculosis.
    - Syphilis.
    - Other infections and parasites.
- Necrotic conditions.
- Ulcers.
- Cicatricial contractions.
- Acquired deformities.
- Effects of occupation on the hand.
- Affections of the nails.
- Affections of the skin.
- Affections of the bursæ.
- Affections of the bones.
- Affections of the joints.
- Affections of the tendons and tendon sheaths.
- Affections of connective-tissue structures:
    - Dupuytren's contraction of the palmar fascia.
    - Contraction of the digital fascia.
    - Hammer finger.
    - General palmar induration.
- Trigger finger.
- Circulatory disorders.
- Muscular affections.
- Nervous affections.
- Senile changes.
- Condition of the hand in general diseases.

Congenital and Developmental Anomalies.

The class of developmental anomalies in general should include all aberrations or faults of development manifesting themselves at any time during the period of development, including not only conditions arising in the prenatal period (as polydactylism), but also those that make their appearance in childhood and up to the time of maturity and complete physical development (as certain forms of hammer finger). In this section it is proposed to consider only certain congenital abnormalities of the hand which develop during the intra-uterine period of existence.

The anomalies of development under consideration embrace the following conditions:

1. Conditions in which there is a deficient degree of development, either (*a*) a deficiency in the *number* of the structural parts affected, or (*b*) a deficiency in their *size*. The congenital numerical deficiencies pertaining to the hand are: *acheiria*, in which the hand is lacking altogether; *ectrodactylism*, in which one or more fingers are missing; and *hypophalangism*, in which the number of phalanges in a digit is below the normal. The congenital deficiencies in size of the hand and fingers will be considered in connection with microcheiria and microdactylism.

2. Conditions in which there is an excessive development; either (*a*) an excess in the number of structural parts, *polycheiria*, *polydactylism*, and *polyphalangism*, or supernumerary hand, fingers, or phalanges respectively; or (*b*) a congenital excess in size, or hypertrophy, which will be considered in connection with cheiromegaly and dactylomegaly.

3. Conditions of perverted development (qualitative or morphological rather than quantitative); as syndactylism, the union of fingers; cleft hand; congenital constrictions; deflections of the hand and fingers (club hand, etc.); congenital dislocations; congenital neoplasms; and various unclassifiable deformities and conditions.

In many cases anomalies of the types mentioned exist separate and distinct; in many other cases anomalous conditions of different types are associated together and coexist in the same member, as where a supernumerary finger is of rudimentary structure, or a club-hand is ectrodactylous.

Subjects exhibiting congenital anomalies of the region under consideration, especially numerical deficiencies, often exhibit other developmental faults or abnormities in other parts of the body, as harelip or cleft palate, thus testifying to the existence of a deep-seated and general developmental vice. Such anomalies of the hand are especially associated with corresponding anomalies of the foot. In many cases hereditary transmission of the deformity is marked.

The causes of these congenital anomalies are obscure. They arise largely from deep-seated and innate tendencies to aberrant development, often hereditary. The aberrant tendency is sometimes very definite and fixed, precisely the same abnormity appearing in different generations. Some cases may perhaps be due to abnormalities of the early environment of the developing embryo.

Another class of causes that produce congenital deformities of the hand is to be found in intra-uterine traumatisms or other prenatal pathological processes. Thus, intra-uterine amputation may cause loss of the entire hand or parts of it; prenatal ulcerations may be followed by abnormal union or adhesions of parts, as in some cases of syndactylism; deformities may perhaps arise from cicatrization or from adhesions to other parts of the fœtus or afterbirth, or in other ways. Deformities caused by such prenatal morbid conditions are, of course, not real developmental aberrations; but as the results produced in the two ways are rarely distinguishable they may be considered together.

Maternal impressions during pregnancy are sometimes adduced in explanation of congenital anomalies of the hand (as elsewhere); as in the alleged case of an officer's wife, who after her husband lost his right hand gave birth to children exhibiting the same deformity. It is very doubtful if maternal impression really plays any part in the production of such deformities. Some alleged instances are coincidences; others are afterthoughts, a past incident being recalled after the birth of an affected child. Considering the difficulty that is found in demonstrating the hereditary transmission of acquired characters, it is obvious that to prove that a developing fœtus can be influenced by maternal impressions is a matter of far greater difficulty.

The use of the *x*-rays now affords means of investigating and diagnosing the precise condition of the bony parts in these deformities that were lacking to the early observers.

Acheiria, or total congenital absence of the entire hand, occurs very rarely. It might arise either as a developmental abnormity or from intra-uterine amputation. It would naturally occur in connection with a greater or less deficiency in development of the upper extremity, as when the limb is entirely wanting (ectromelia) or is partly wanting (hemimelia). When the upper extremity is only partly developed, it is more usual for a rudimentary hand, or one or more fingers rudimentary or well developed, to be present on the stump than for all trace of a hand to be absent. Typical acheiria may, however, occur, as in a case reported by James Finlayson (*Archives of Pediatrics*, Philadelphia, 1890, vol. vii., p. 674).

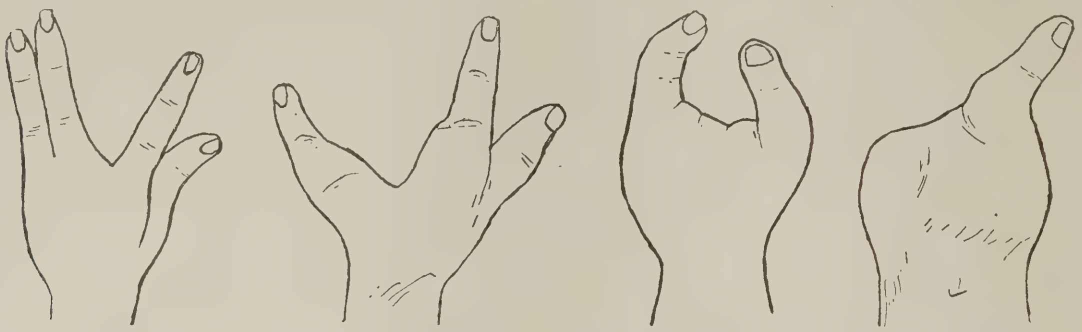

Fig. 2457. Fig. 2458. Fig. 2459. Fig. 2460.

Figs. 2457 to 2460.—Ectrodactylism.

Fig. 2457.—Congenital Absence of Middle Finger. (Fort.)
Fig. 2458.—Absence of Middle and Ring Fingers. (Clutton.)
Fig. 2459.—Absence of Index, Middle, and Ring Fingers—"pince de homard." (Annandale.)
Fig. 2460.—Absence of Four Digits. (Annandale.)

Phocomelus is the rare condition in which the hand (or foot) is attached directly to the trunk, like the flipper of a seal, the upper (or lower) extremity uniting it to the body being absent or extremely abbreviated.

Ectrodactylism consists in the congenital absence of one or more fingers (or toes), resulting either from defective development or intra-uterine amputation. It is one of the less common forms of congenital abnormity of the hand, occurring considerably less frequently than polydactylism or syndactylism. In the cases that do occur both hands are usually affected simultaneously; less commonly either hand may be affected alone. Other deformities of the hand or upper extremity, or of the foot or other parts of the body, are apt to coexist with ectrodactyly. The finger involved may alone be wanting, the corresponding metacarpal bone being present; or the metacarpal bone may also be lacking; even the corresponding portion of the carpal bones is sometimes wanting. Owing to the association of other deformities and abnormal conditions the fingers present may be useful and functional, or not. The influence of heredity in reported cases is well marked. Some cases of apparent ectrodactylism may arise from intimate union of two digits.

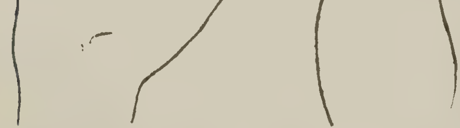

Fig. 2461. Fig. 2462.

Figs. 2461 and 2462.—Hypophalangism. (Annandale.)

Fig. 2461.—Absence of Distal Phalanges of Three Fingers.
Fig. 2462.—Absence of all the Phalanges of all the Fingers.

Any of the fingers, and from one to four in number, may be lacking. The particular fingers that may be involved, and the extent to which the metacarpus and carpus may be affected, give rise to an indefinite number of possible combinations that may occur. There are two or three particular conditions that occur with such comparative frequency, however, that they may be specially mentioned.

In a considerable proportion of cases the thumb alone is missing. This occurs especially in association with congenital absence or deficiency of the radius. Nondevelopment or partial development of the radius is in nearly all cases accompanied by absence of the thumb, its metacarpus, and one or more of the corresponding carpal bones (Figs. 2475, 2476, 2477). In the case of absence of radius illustrated in Fig. 2477, there is a rudimentary thumb present, but articulated to the head of the metacarpal bone of the index finger.

It is rare for any of the digits other than the thumb to be lacking alone, it being more common for two or three fingers to be absent than one of them only.

One of the common forms of ectrodactylism consists in the absence of the index, middle, and ring fingers. This leaves the thumb and little finger, often opposed to each other, somewhat like the jaws of pincers; the term "pince de homard" (lobster claw) has been applied to this particular condition (Fig. 2459).

Little can be done in the way of treatment to improve ectrodactylism, unless by amputation or other operation an unsightly deformity may be removed or some impediment to function obviated.

Hypophalangism is the congenital absence of one or more phalanges and the corresponding soft parts from a digit. It is an abnormity of somewhat similar character to ectrodactylism, the deficiency being less in degree. In hypophalangism either one, two, or all three phalanges may be lacking, the finger in the cases in which all three phalanges are missing (Fig. 2462) being represented simply by a rudimentary nodule of soft tissue perhaps surmounted by a nail. When all traces of the hard and soft tissues of the finger are lacking, the condition becomes one of ectrodactylism. Hypophalangism is a very rare deformity, and may occur in association with polydactylism or ectrodactylism, supernumerary fingers being often only partially developed. The condition is one form of brachydactylism or short finger.

Congenital anonychia or absence of the nails will be spoken of in connection with the affections of the nails.

POLYCHEIRIA, or *supernumerary hand* (double hand, dicheiria, also called, not very aptly, bifurcated, or bifid, hand). The development of a supernumerary hand, in addition to the normal hand, is a conceivable condition, but is exceedingly rare. A very few cases are on record which may be classified as double hand, though such cases merge into polydactylic conditions. In these cases the double hands each possessed from eight to twelve fingers in all; the two hands, which were not normally developed, were either united more or less along the adjacent sides, or the two parts were separated by a bifurcation extending to the carpus. Each hand had its own set of muscles and tendons, so that the two parts could close over and grasp each other; this feature is a distinguishing characteristic between double hand and simple polydactylism. The only treatment called for is the removal of useless or unsightly digits to improve the appearance or function of the member.

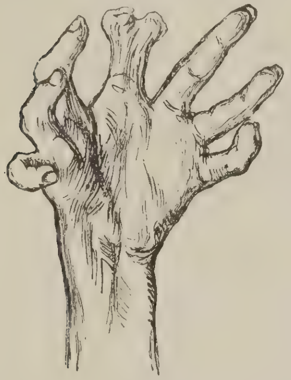

FIG. 2463. — Double Hand. (Clutton.)

POLYDACTYLISM, or *supernumerary finger* (or toe), is the presence on the hand or foot of more than the normal number of digits. The supernumerary fingers vary in the degree of their development from those that are rudimentary to those that are quite perfect and well developed. This is one of the commoner of the developmental anomalies of the hand. More often there is only one supernumerary finger, but a greater number may be present. One case is recorded in which the subject possessed thirteen fingers on each hand and twelve toes on each foot; another case had twelve fingers on each hand; several cases of ten fingers on the hand have been observed and from that number down the cases become more numerous. It is more usual for both hands to be affected together than for one hand to be involved alone, and the feet are apt to exhibit a corresponding abnormality.

Syndactylism is sometimes associated with polydactylism. Hereditary transmission has been observed in numerous cases. The cause of the anomaly evidently rests in an innate aberrant developmental tendency.

All the parts that enter into the structure of normal fingers may also be present to a greater or less degree in supernumerary digits, bones, joints, tendinous and muscular attachments, nails, etc. The most perfectly developed supernumerary fingers are as complete and mobile and useful in all respects as the ordinary fingers; from this perfectness the degree of development ranges down to rudimentary structures which are distinguishable from congenital tumors only by the presence of bony or cartilaginous tissue or a rudimentary nail. The muscular connection and the movability and functional value also range from a good degree of usefulness down to immovable and useless digits.

There is an indefinite variety in the possible forms and combinations in which the deformity may be manifested. Thomas Annandale's classification, which seems as satisfactory as any proposed, is as follows:

1. Cases in which the supernumerary digit is a rudimentary and deficient structure attached to the hand or another digit by soft tissues or a narrow pedicle and without any articulation (Fig. 2464). The most rudimentary of this class of supernumerary finger may practically amount simply to a tumor, the digital nature of which is shown only by the presence of bony tissue in its interior or a rudimentary nail. Supernumerary digits of this kind are usually situated on the ulnar side of the hand or little finger, but they occasionally occur on the radial side or any other portion of the hand. These digits usually have very little mobility or functional action.

2. Cases in which the supernumerary digit, more or less well developed and free in its distal portion, is given off from and articulates with the side or head of a metacarpal or phalangeal bone belonging to a normal digit, or common to the two digits (Fig. 2465). Some of these cases appear as if a finger were bifurcated, the two divisions being nearly equal and symmetrical: in other cases one of the digits from its less development or asymmetrical position is evidently supernumerary. Often the extra digit is not very movable or useful, but sometimes it has good functional power.

The supernumerary digit may articulate with (*a*) the side of the metacarpal or phalangeal bone common to it and the normal finger, in which case it has its own articular and synovial structure entirely distinct from the corresponding articulation of the normal finger; or it may articulate with (*b*) the head of the common metacarpal bone or phalanx. In the latter case there may be two separate articulations, with separate joint cavities, or there may be only one synovial cavity common to the articulations of the two digits. Sometimes the metacarpal or phalangeal bone to which the two digits are attached bifurcates and has a separate articulation on each of the two heads. It is important to bear in mind the nature of the articulation in amputating in these cases.

The thumb is not uncommonly the seat of this form of polydactylism, being either bifurcated (Fig 2465) or giving off a supernumerary thumb from its side.

3. Cases in which the supernumerary finger is a practically perfect and fully developed digit, complete in itself in all its parts, and distinct from the other fingers, having its own phalanges, metacarpal bone, and attachment to the carpus (Fig. 2466). Such fingers are usually as useful and good as the normal fingers. Some cases of double hand may be partly regarded as instances of this form of polydactylism. Supernumerary fingers in rare instances are associated with a corresponding excess of development in the forearm, as with a supernumerary radius.

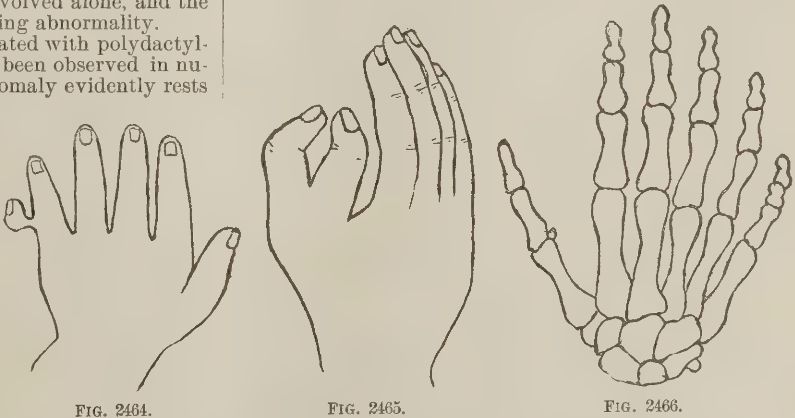

FIG. 2464. FIG. 2465. FIG. 2466.

FIG. 2464, 2465, AND 2466.—Polydactylism. (Annandale.)

4. Cases in which the supernumerary digit is intimately

united along its whole length to the normal digit—that is, a combination of syndactylism with polydactylism. The supernumerary digit may be more or less well developed, having separate metacarpal and phalangeal bones of its own, or possessing only phalanges which are articulated to the metacarpal bone or a phalangeal bone common to it and the normal digit. Such a double finger is broad and is apt to possess two nails. The thumb is said to be oftenest affected in this manner.

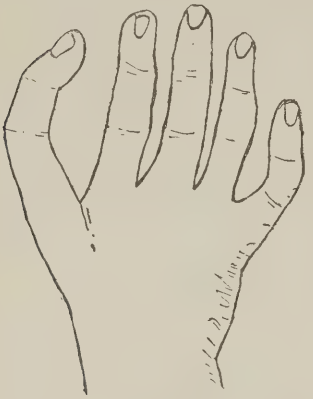

FIG. 2467.—Polyphalangism, the Thumb Possessing a Supernumerary Phalanx. (Annandale.)

The treatment of polydactylism consists in amputation of the supernumerary digits, for the purpose of improving the appearance of the hand or removing useless structures that may be an actual impediment to the function of the hand or impair its proper development. As a supernumerary digit tends to retard and impair the development of the normal finger to which it may be attached, amputation should be performed as early in life as is practicable and convenient. In some instances there has been observed a tendency for new rudimentary digits to grow out from the stumps of amputated supernumerary fingers.

In considering and practising amputation, however, careful attention must be paid to the danger and consequences of injuring a joint of one of the normal fingers and thus causing an ankylosed and stiffened digit that may be worse than the original polydactylic condition. When the supernumerary finger is connected by soft tissues only, or has its own distinct and separate articulation and joint cavity, the operation is simple and void of evil consequences if properly carried out so as not to interfere with other joints. But in those cases in which the extra digit has an articulation in common with the normal digit or articulates with the common carpal joint, it must be remembered that the process of disarticulation will necessarily cause an opening to be made into the joint of the finger that is to be left, thereby rending it extremely liable to ankylosis. In such cases it may be preferable to amputate by cutting through the base of the bone near the joint, but without opening the joint itself. This will necessitate leaving a small portion of the proximal end of the supernumerary digit, but any slight deformity thus occasioned may be preferable to the impairment of function that will be caused by a stiffened finger. In such cases the use of the x-rays prior to operation may afford valuable information as to the precise relations of the articulations.

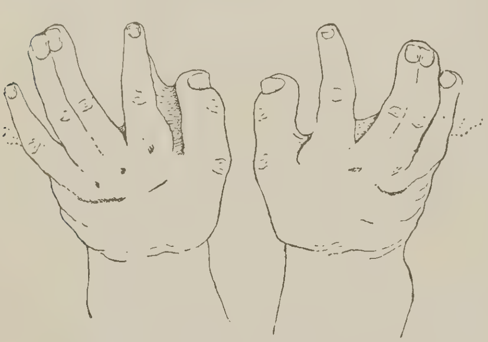

FIG. 2468.

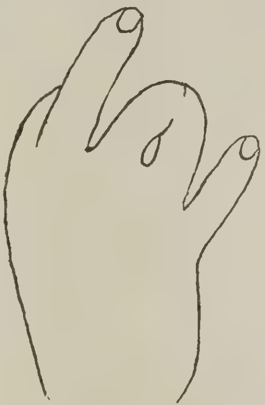

FIG. 2469.

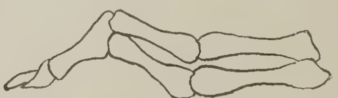

FIG. 2470.

FIGS. 2468 TO 2470.—SYNDACTYLISM.

FIG. 2468.—Syndactylism. (Clarke.) The dotted lines represent amputated supernumerary fingers.
FIG. 2469.—Union of Distal Portions of Fingers. (Annandale, after Otto.)
FIG. 2470.—Fusion of Distal Phalanges. (Annandale, after Otto.)

POLYPHALANGISM (or "hyperphalangism") is the very rare condition in which a digit possesses a supernumerary phalanx, or more than the normal number of phalanges (Fig. 2467). In the cases that occur the thumb is the digit oftenest affected, though cases involving the index and middle fingers have been observed. In a very few instances in which a supernumerary phalanx was present, the phalanges generally were so shortened that the condition of brachydactyly or short finger was manifested.

SYNDACTYLISM

consists in the union, fusion, or growth of adjacent digits to each other by their contiguous sides. It usually arises as a true developmental anomaly from an innate aberrant tendency of growth; or it may exceptionally be acquired, either in the intra-uterine period or at any time during life, from the adhesion or growth together of ulcerated digital surfaces or from cicatricial contractions. The site of union may extend the entire length of the fingers; or it may involve only the proximal portion of the fingers, to a varying extent, leaving the distal portions free and separate; or, rarely (probably from the union of ulcerated surfaces), the distal portions of the fingers may be united and the proximal portions separate (Fig. 2469). The union may consist of a thin fold or web of skin stretching across, between, and connecting the two fingers, the true "webbed fingers"; or the connection may be more intimate, involving more or less of the subcutaneous and internal tissues of the fingers, ranging up to cases in which even the bones are united. Cases have been observed in which the distal phalangeal bones were fused together, while the proximal phalanges were separate (Fig. 2470). Two fingers alone may be united, or three, or four, may be connected together; rarely all the digits are bound together in an unshapely deformed mass. The index and middle fingers are not uncommonly united.

Syndactylism is not a very uncommon condition, and is one of the most frequently observed developmental anomalies of the hand. In the true congenital or developmental form of syndactylism, hereditary transmission is often observed, and both the hands are frequently involved together, though the fingers affected may be different on the two sides. The hands and feet are often involved simultaneously. In acquired syndactylism heredity is of course not observable, and only one hand would ordinarily be affected.

Treatment.—The only treatment of this condition is operative. The best age for operating is usually stated as from four to six years, when the fingers are of sufficient size for easy management and control, and before growth is materially interfered with by the deformity. In most cases it is easy enough to effect a separation between the digits, but to prevent the raw surfaces from growing together or to obviate a recurrence of the deformity from cicatricial contraction, is often a matter of some difficulty and requires special plastic surgical measures. It is necessary to pay special attention to the denuded surface in the interdigital angle.

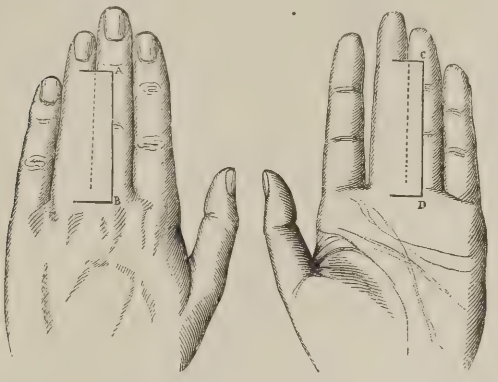

FIG. 2471.—Didot's Operation for Syndactylism, Dorsal and Palmar Views, Showing Primary Incisions. (After Stedman.)

When the web is broad and thin successful and permanent separation of the united digits may be obtainable by the simple method of cutting the web in two longitudinally down its middle line, and suturing the edges of the incised skin together over each finger. The edges of the wound in the interdigital angle should especially be brought together and sutured. The fingers should, as in all operations for syndactylism, be dressed separately, so as to keep the wounded surfaces apart until healing is complete. Recurrence may, however, follow this procedure.

In some cases, especially when the union is very close, as the preliminary step in treatment an opening may be made through the tissues connecting the digits at the proximal end of the contemplated separation. In this opening a glass or metal tube, wire, or a bundle of silkworm gut is kept until the sides of the hole heal over and become completely lined with epithelium. When this is well accomplished the fingers are cut apart for the remainder of the distance, and the edges of the wounds are approximated and sutured in the best manner practicable. The preliminary establishment of a healed surface at the interdigital angle or commissure prevents the recurrence of union from that point.

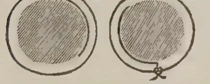

FIG. 2472.—Didot's Operation for Syndactylism, in Cross Section, Showing Method of Dissecting Off and Suturing the Flaps. (After Stedman.)

Didot's plastic operation (Figs. 2471 and 2472) appears to be the most frequently employed for syndactylism, especially for cases with a long and thick web. By this method longitudinal incisions are first made through the skin along the middorsal line of one finger and the median palmar line of the other finger (Fig. 2471). Beginning at these incisions rectangular flaps are then dissected off, and the tissues uniting the two fingers are cut through so that one of the digits has a flap adhering to its dorsal surface and the other a flap adhering to its palmar surface. Each flap is then brought around the finger to which it is attached and its margin sutured neatly to the edge of the skin so as to cover the surface denuded by dissecting off the flaps. The method of forming the flaps and of suturing them in their new positions is graphically illustrated in Fig. 2472. This procedure keeps the healing surfaces well separated, and thus obviates readherence. It is probable that flaps should also be drawn together and sutured in some such manner as is employed in Norton's operation in order to close and cover the raw surface in the interdigital angle. From the stretching of the flaps sometimes necessitated there may at times be some tendency to sloughing of the tissues; but in general the results of Didot's operation are very satisfactory and successful.

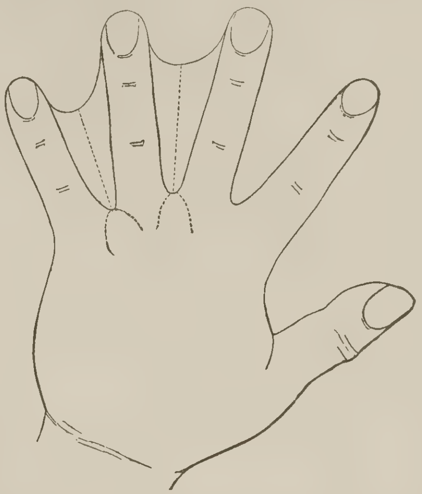

FIG. 2473.—Norton's Operation for Syndactylism. (From Bradford and Lovett.)

Norton's operation (Fig. 2473), which is recommended for cases in which there is a short but ample web, consists in the formation of horseshoe-shaped flaps, dorsal and palmar, which are stretched and sutured together so as to cover the interdigital angle. The web is divided lengthwise, and the divided edges are brought together along each finger.

Zeller's operation (Fig. 2474), which is recommended for cases similar to those for which Norton's is employed, consists in the formation of a triangular dorsal flap, which after section of the web is brought into the interdigital angle and sutured in place. Agnew's operation is similar to Zeller's.

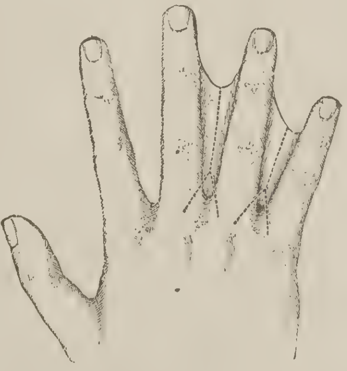

FIG. 2474.—Zeller's Operation for Syndactylism, Showing Lines of Incision and Outlines of Flaps (which are not shown sufficiently long). (Treves.)

Fowler's operation (Dennis' "System of Surgery," vol. ii., p. 186) is recommended for obstinate and intractable cases. In this procedure a preliminary longitudinal opening or slit is made through the web between the proximal ends of the proximal phalanges, at the site of the future interdigital angle. From the dorsum of the hand two long narrow flaps are then cut, one on each side of this opening and with their attached bases near the slit. The flaps are then twisted around a quarter of a circle and drawn through the slit so that the skin surfaces of the flap are opposed to each other and their denuded surfaces are brought in contact with the raw surfaces of the slit, with which they are designed to become united. The flaps should be long enough to project through the palmar aspect of the slit about a centimetre, and they do not require to be sutured in place. The areas left by the removal of the flaps on the back of the hand can be closed by sutures. When the wounds heal, there will be a permanent opening through the web, lined with skin. The remainder of the web is then divided, and the healed commissure will prevent recurrence of the mal-union.

Cleft Hand.

The contrary condition to syndactylism, the union of parts normally separate, is cleft hand, or a separation of parts normally united. Cleft hand consists in the separation of, or division between, adjacent fingers extending farther toward the carpus than normal, that is, into the metacarpal region. It is a very rare condition, and is almost invariably associated with other developmental anomalies. In nearly every case it is associated with ectrodactylism, especially with lack of the middle finger (see Figs. 2457 and 2458); other anomalies, as syndactylism, may also be present. In a case reported by Charles N. Dowd (*Annals of Surgery*, Philadelphia, vol. xxiv., 1896, p. 211), the number of fingers was normal, but there was syndactylic union of the metacarpal bones of the ring and little fingers; the unsightly appearance of this case was relieved by a plastic operation. This condition should not be confounded with dicheiria, to which the term "bifid hand" is often rather inappropriately applied.

Congenital Constrictions.

Congenital annular constrictions of the fingers, as well as of other portions of the extremities, have been observed, but are very rare. They are apparently produced by tight turns of the umbilical cord or of amniotic bands around the members, constricting the tissues; they are hence produced in the same manner as are intra-uterine amputations but with the constriction not carried to a sufficient degree to cause complete amputation.

Deflections of the Hand and Fingers.

A large proportion of the deformities of the hand consists of deflections or deviations of the hand, fingers, or phalanges from their normal direction or position. The deflection may be in a forward or palmar direction (that of flexion), a backward or dorsal direction (superextension), or a lateral direction (either to the radial or to the ulnar side), or in intermediate directions. These deviations are often called contractions; but this designation is not very satisfactory as a general term, since all the deflections are not due to a contraction or pull.

The point of deflection is in almost all cases at one of the joints, either the wrist joint, or the metacarpo-phalangeal joints, or the interphalangeal joints. Occasionally the deflection may arise in the course of the bones, as in mal-union at an angle after fracture, or curvature of the bones in osteomalacia.

No complete and systematic classification and nomenclature for these deflections have been formulated. Deflections of the hand at the wrist joint in the different directions, especially the congenital cases, have been called "club hand," after the analogy of club foot. No such designations as club-finger or club phalanx have been employed, though such terms or their equivalents would be useful. The term "clinodactyly" has been employed as a generic designation for deflections of the fingers (Fort), but has not come into general use.

Using as a basis the situation and the direction of the deflection, the following scheme for the anatomical classification and nomenclature of the various deflections of the hand and fingers is proposed and will be used here:

Deflections of the hand at the wrist joint—"club hand"; forward deviations, *manus flexus;* backward deviations, *manus superextensus;* deflection to the radial side, *manus varus;* deflection to the ulnar side, *manus valgus.*

Deflections of the fingers—"clinodactyly": forward, *digitus flexus;* backward, *digitus superextensus;* to the radial side, *digitus varus;** to the ulnar side, *digitus valgus.** For the thumb, the terms *pollex flexus, pollex superextensus, pollex varus,* and *pollex valgus* can be used for the corresponding deflections. These terms relating to the fingers could be employed for deflections at either the metacarpo-phalangeal or interphalangeal articulations; but if greater precision were desirable where the deviation was at an interphalangeal joint and the bending involved only the middle or distal phalanx, the terms *phalanx flexa, phalanx superextensa, phalanx vara,* and *phalanx valga* could be employed for the forward, backward, radial, and ulnar deflections respectively.

For deflections in the intermediate directions compound terms could be employed as in talipes.

This terminological classification would be practical and useful for placing and designating the anatomical condition or particular form of deviation present in particular cases; but it would not be a satisfactory classification from an etiological or pathological standpoint or for clinical purposes, since different deflections may be produced by the same cause, or the same deflection may arise from different causes. In most cases the deflections are simple and distinct enough to permit of ready classification.

Deflections of the hand or fingers may be congenital, arising from developmental anomalies, or acquired. They occur in connection with a considerable variety of etiological and pathological conditions, which may be briefly summarized as follows:

Dermatogenous deflections, in which the deformity is produced by lesions of the skin, as scleroderma.

Desmogenous deflections, produced by lesions of connective-tissue structures, fascias, ligaments, etc., as cicatricial contractions, Dupuytren's contraction of the palmar fascia, hammer finger, contraction of the digital fascia.

Arthrogenous deflections, produced by lesions of the articulations, as arthritis of various forms (gouty, rheumatic, rheumatoid, tuberculous, etc.), dislocations, altered configuration of joints (developmental, senile, inflammatory), ankylosis in malposition.

Osteogenous deflections, from lesions in the bones, mal-union after fracture, osteomalacia, abnormal development.

Tendinous deflections, from injuries, division, or adhesions of tendons.

Muscular or myopathic deflections, from abnormal muscular conditions, as abnormal development, myositis, atrophies, ischæmic paralysis, and abnormal innervation.

Nervous or neuropathic deflections, from paralytic, spastic, or trophic conditions.

Deflections of the fingers and phalanges from their normal position and direction are much commoner than are deflections of the hand at the wrist joint, partly because the small digital articulations are more subject to arthritic conditions, partly because the muscular and motor mechanism of the fingers is more extensive and more complicated, and hence more exposed to morbid influences. Of the deflections of the fingers the forward deviations are much the commonest and most varied as to cause, while the lateral and backward deviations are much less frequent.

As there is so great a diversity in the etiological and pathological nature of these deflections, it is more satisfactory to treat the different varieties in connection with the various pathological conditions with which they are associated than to consider all the hand and finger deflections in one general group. Consequently at this point consideration will be given only to club hand, congenital deflections of the fingers, lateral deflections of the fingers, and backward deflections of the fingers, reserving the remaining forms of deviation for treatment in their appropriate connections.

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* These designations are as proposed by Joachimstal.

Club Hand.—This term in its most general sense could be applied to all deflections of the hand at the wrist joint, congenital or acquired, but as ordinarily used it is chiefly employed to designate only the congenital forms of the deformity.

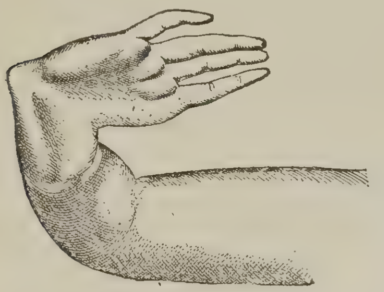


Fig. 2475.—Congenital Club Hand, with Absence of Radius and Thumb. (Hoffa.)

The cases of congenital club hand, which is a rare condition, may be divided into some three classes, as follows:

1. The first class comprises those cases depending on contractions and altered anatomical conditions of the carpal structures in a manner entirely analogous to congenital club foot. This form of congenital club hand is exceedingly rare, as the hand is very little subject to the developmental anomalies and intra-uterine conditions that give rise to talipes.

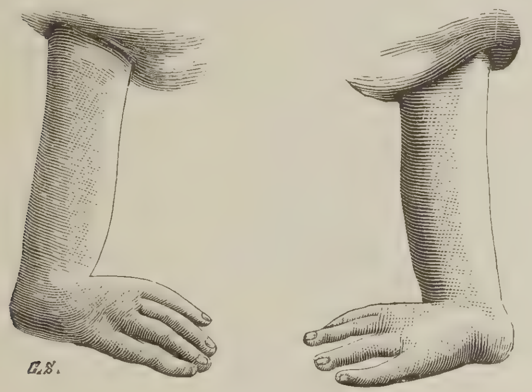


Fig. 2476.—Congenital Club Hand, with Deficiency of Radius, Dorsal View.

2. Of the rare cases of congenital club hand that do occur, the largest proportion consist of anomalies associated with developmental deficiency or absence of the radius. This and the following class of deformities are caused by conditions quite different from those that give rise to ordinary talipes; the term club hand is, however, generally extended to the cases associated with defective development of the bones of the forearm. In this form of club hand the radius is either totally absent or only partially developed, the distal extremity being deficient in the latter case. The hand is articulated on the lateral aspect of the ulna in the position of manus varus (Figs. 2477, 2478) at a considerable and even a right angle to its normal situation. The thumb and corresponding carpal bones are usually lacking, though exceptionally present, as in Fig. 2477, in a rudimentary condition and transposed situation.

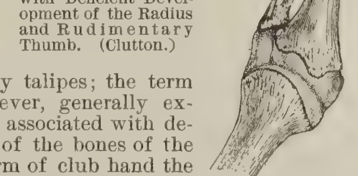


Fig. 2477.—Club Hand, with Deficient Development of the Radius and Rudimentary Thumb. (Clutton.)

3. Much more rarely than the radius, the ulna is absent or defective, giving rise to an abnormal position and ectrodactylous condition of the hand corresponding to the radial deformity.

The treatment of congenital club hand, if undertaken sufficiently early in life while the joint structures are pliable and adaptable, consists of gradual correction of the deformed position with maintenance of the hand in the improved position until permanent results are attained. Violent and abrupt measures are not generally desirable, but the correction should be accomplished by gradual steps, apparatus (Fig. 2479), splints, or plaster-of-Paris dressings being employed in the intervals to maintain and render permanent each step gained. Massage and electricity may be useful to improve the nutrition of the muscles of the forearm.

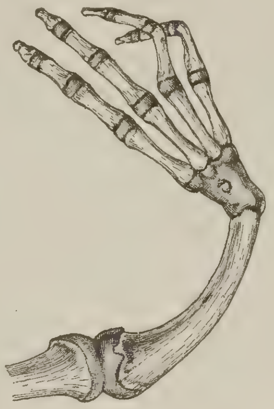


Fig. 2478.—Club Hand, with Congenital Absence of Radius and Thumb. (Clutton.) From same case as that illustrated in Fig. 2477.

In older patients the joint is apt to become so fixed that attempts at correction of the deformity may result in impairing the usefulness of a hand, which, though deformed and unsightly, still has good functional power and is a useful member. Treatment in such cases should be very conservative, and utility should not be sacrificed for the sake of appearance.

Congenital and Developmental Deflections of the Fingers.—Congenital deflections of the fingers are rare, while the acquired deviations are common. The common form of hammer finger is a developmental anomaly scarcely manifest at birth but gradually appearing during the period of development. Tamplin reported an instance of congenital contraction of the thumb in a flexed and adducted position, in a case of double talipes and contraction of the knee. Congenital deflections of the digits or phalanges are most commonly in a lateral direction.

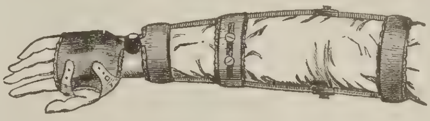


Fig. 2479.—Apparatus for Treatment of Club Hand. (After Dubreuil.) At the wrist is a universal joint to allow for movement and fixation in various positions.

Lateral Deflections of the Fingers or Phalanges may be congenital and developmental, or acquired. The acquired forms arise chiefly from cicatricial contractions, joint changes (especially arthritis deformans), dislocations, injuries, ankylosis in malposition, senile changes, or in association with hypertrophied fingers. Of these a general deviation of the four ulnar fingers toward the ulnar side is a com-

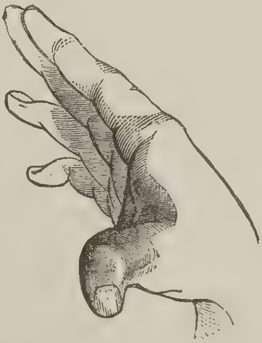


Fig. 2480.—Congenital Radial Deflection of Distal Phalanx of Thumb. (Gross.)

mon and characteristic condition in certain senile and rheumatoid cases.

A small number of cases have been reported in which the distal phalanx of the thumb has been congenitally bent laterally, either to the ulnar or to the radial side, at a sharp angle. Some of these cases were hereditary, others were associated with other deformities, as club foot; the cause of this abnormity is hence developmental. The treatment, if undertaken sufficiently early, should consist in gradual correction of the deformity and fixation by splints until permanent improvement is obtained. Removal of a wedge-shaped piece of bone from the phalanx has proven successful in one case; while division of the lateral ligament and exsection of a portion of the head of the phalanx did not give satisfactory results in another instance.

There is another well-marked class of lateral deflections of the phalanges, affecting chiefly the little fingers, which occurs occasionally, often associated to a certain degree with hammer finger. Exceptionally the deflection may be toward the ulnar side, or the middle phalanx may be the one bent, or the ring finger, or some finger other than the little finger, may be affected; but usually this abnormity manifests itself as a radial deflection of the terminal phalanx of the little finger (phalanx vara). The deviation is not generally more than about twenty-five or thirty degrees, and both little fingers are usually affected together. Anderson states that among eight hundred school children there were six cases of such lateral deflections, in five of which the little finger on both hands was affected, and in one the ring finger of one hand was involved. This lateral phalanx deflection is not infrequently exhibited by little fingers that are also affected with the condition termed hammer finger; and the writer has observed one case of phalanx vara of both little fingers in a woman who had a hammer toe but no hammer fingers, but whose mother and mother's brother had hammer fingers. Radial deflection of the distal phalanx of the little finger is said to be common in idiots of the so-called Mongol type. The condition is of developmental origin caused by irregular development of the phalangeal articulation. The abnormity is somewhat unsightly, but is not troublesome in any other way. The only advisable treatment is the use of splints for a time to straighten the finger.

Backward Deflections of the Fingers (digitus superextensus).—Superextensions of the fingers or phalanges are among the less common of the deflections of the fingers; they are mostly acquired, and are due to various conditions.

The terminal phalanx of the thumb in many persons is capable of extension backward from the straight line to a marked degree, flexion not being interfered with; this is a normal developmental condition. The terminal phalanges of the other fingers are occasionally markedly extensible backward, and in such cases power of flexion is sometimes somewhat impaired.

Cicatricial contractions following dorsal ulcers, contractions of the dorsal digital fascia, joint lesions like arthritis deformans, adhesions of extensor tendons, section of flexor tendons, spasm of extensor muscles, paralysis of flexor muscles, are the other principal causes of superextended fingers or phalanges. In a considerable proportion of cases of hammer finger there is a hyperextended condition of the proximal phalanges of the affected fingers; and superextension of the distal phalanges in hammer fingers has been observed. In Dupuytren's contraction the writer has seen in one case a superextension of the distal phalanx caused by a band of contracted fascia that crossed from the palmar to the dorsal aspect of the finger. In dactylomegaly there is not infrequently phalangeal superextension.

The treatment of digital and phalangeal superextensions must be guided by general principles and the conditions present. Some cases will hardly require treatment, others are insusceptible of improvement. Gradual or forcible correction of the deformity with fixation by splints, division of contracting tendons or fibrous bands, or lengthening or shortening of tendons by plastic procedures may result in lessening the deformity and impairment of function.

Microcheiria and Microdactylism,

or abnormally small size of hand or fingers, may be due to retarded, deficient, or arrested development, or to atrophy or retrogression after full development has been once attained. Both congenital and acquired cases are distinguishable.

Brachydactyly, or short finger, is a form of microdactyly in which the deficiency in size affects especially the length of the finger.

In dwarfs and in conditions like achondroplasia, the hand and fingers are small but not diminished in size in proportion to the rest of the body or of the upper extremity; such cases are hardly to be classed as real microcheiria or microdactyly, in which the small size is relative as well as absolute.

Brachydactyly is caused by congenital absence of phalanges (hypophalangism) or by abnormal shortness of the phalanges or metacarpal bones. Cases have been observed in which a supernumerary phalanx even was present, but with sufficient abbreviation of the phalanges to constitute a condition of brachydactyly. Brachydactyly and other forms of congenital microdactyly are rare. Deficient size of the thumb, apparently developmental, occurs in a certain proportion of the cases of ossifying myositis; in this disease a corresponding anomaly of the great toes occurs much more frequently. Fingers associated with developmental abnormities, such as supernumerary or syndactylic digits, are apt to be retarded or stunted in development unless the impediment is early removed. Injuries or diseases affecting digits during the period of development, in infancy or childhood, may arrest or retard their growth so that they may not attain full development. Loss of tissue or destruction of bone from injuries, inflammation (tuberculosis, etc.), ulceration, and the like, will if not replaced result in diminution of size. After full growth is attained atrophy and decrease in size may result from injuries, local disease, trophic influences from nervous lesions, etc.

Hypertrophy of the Hand or Fingers

(cheiromegaly or macrocheiria, dactylomegaly, megalodactylism, or macrodactylism).—Aside from such conditions as neoplasms, œdema, and dactylitis, enlargements and hypertrophies of the hand and fingers are mostly comprehended under the following groups:

Congenital and idiopathic hypertrophy.
Elephantiasis.
Gigantism.
Acromegaly.
Hypertrophic pulmonary osteo-arthropathy.
Hippocratic or clubbed fingers.
Myxœdema.
Syringomyelia.

Congenital and Idiopathic Hypertrophy.—The fingers, hand, and more or less of the upper extremity are sometimes the seat of a peculiar hypertrophy, which, though rare, presents a well-marked clinical type. This hypertrophy is of the same general nature as the condition called "congenital hypertrophy" which affects various other parts of the body, though the fingers are a favorite seat. Sometimes other parts of the body are affected along with the hand, as in the unilateral hypertrophy where the upper and lower extremity on the same side are enlarged.

When the upper extremity is involved it is far commoner for a portion only of the fingers or of the hand to be hypertrophied, the remaining fingers being normal; very rarely the entire extremity may be enlarged. Sometimes even when there is a general enlargement of the limb, some of the fingers are relatively much more enlarged than the others.

The hypertrophy is often, though not always, manifest at birth, the affected fingers being then appreciably and materially larger than the others. Further enlargement proceeds progressively, or may take place rapidly at some time during the period of development. Cases of a high degree of hypertrophy and deformity are exhibited in young children, though the enlargement may develop even in adults. The cause of the hypertrophy is apparently some idiopathic developmental derangement, the precise nature of which is unknown. The condition is sometimes called congenital elephantiasis, and has been thought by some to be a form of elephantiasis. Some of the cases reported, indeed, may have been real instances of elephantiasis. But if the term elephantiasis be limited to hypertrophies produced by occlusion of the lymph vessels, especially by the filaria, there is probably a genuine difference between the two conditions. Hereditary transmission of congenital dactylomegaly has not been especially noted.

The hypertrophy often does not involve all the tissues uniformly, but affects especially the bony, fatty, and vascular tissues. The bones are hypertrophied, and sometimes there are joint lesions. The adipose tissues are often relatively increased, even to the production of lipomatous tumors. Areas of excessive development of vascular structures are frequently exhibited, in the form of angiomata, angiectases, vascular nævi, varicose veins, lymphangiomata, etc. The arteries are said not to be enlarged so much as the veins and capillaries. Muscular strength is sometimes increased, often not, but the usefulness of the member is often impaired. The skin is usually not greatly altered. Syndactylism is sometimes present. Frequently some of the hypertrophied phalanges or fingers are deflected laterally or backward, from articular changes. The metacarpal portions of the affected fingers may, or may not, partake of the hypertrophy.

The enlargement is both in length and, markedly, in thickness. Various gradations of hypertrophy may occur, from slight enlargement up to great deformity and disability. In typical cases the overgrowth is frequently gigantic, so that the member may be highly deformed, unsightly, and useless. Increase of the middle finger, for instance, to a length of 13, 14, or 16 cm. (6½ in.), and to a circumference at its base of 32 cm. (13 in.), has been noted in more than one case. In one instance the hand weighed twelve pounds.

This hypertrophy is in the great majority of cases unilateral, and only exceptionally are both hands affected. In the unilateral cases the right and left hands are involved with about equal frequency, with perhaps a slight difference in favor of the right. In the bilateral cases different fingers may be affected on the two hands. The middle and index fingers are much the most frequently involved, the middle more often than the index finger. The thumb is affected in a considerable proportion of the cases, the ring and little fingers infrequently. The three radial digits are therefore much the most liable to the disease. It is more usual for two or more adjacent fingers to be hypertrophied together than for one finger to be affected alone, though any of the digits may be enlarged alone. The commonest combinations are for the thumb, index, and middle fingers, or for the index and middle fingers to be affected together, next for the middle finger to be hypertrophied alone; the other fingers and combinations are less frequently involved.

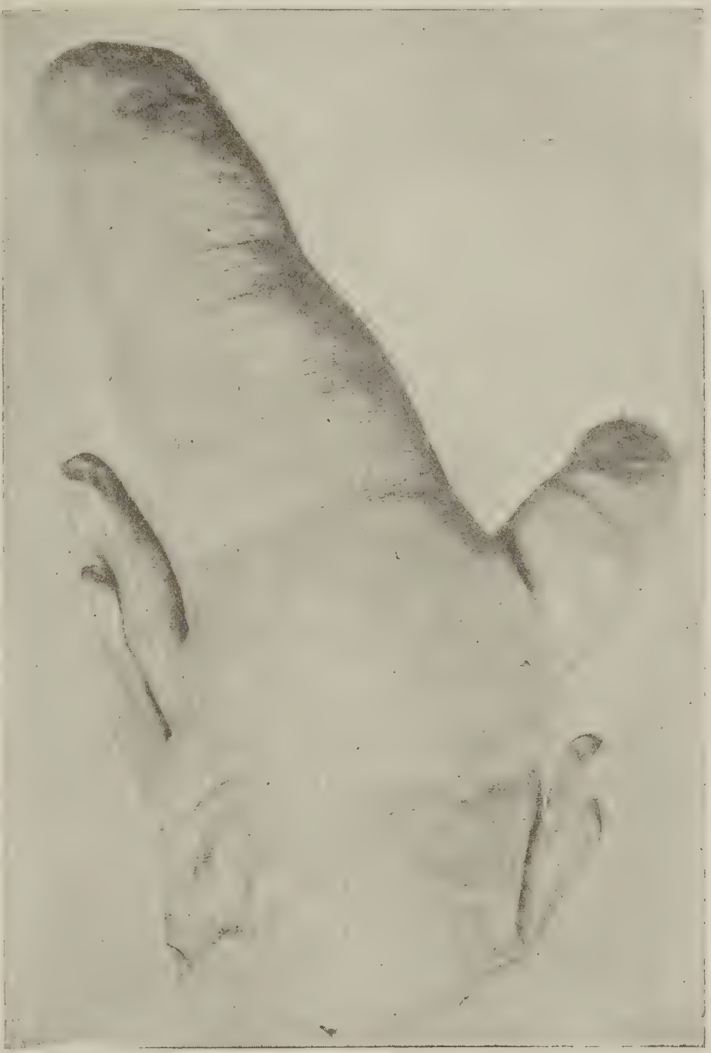


FIG. 2481.—Congenital Hypertrophy of Middle and Index Fingers in Mulatto Girl Aged Eleven Years; Reported as a Case of Congenital Elephantiasis. (T. L. Terry.)

Treatment of congenital dactylomegaly: In incipient cases ligation of the tributary arteries may be tried with a view of diminishing the supply of nutriment and hence retarding the hypertrophic process; success cannot be very confidently expected for this procedure. Compression of the growing fingers offers little hope of successful results. When fully developed amputation may be requisite to improve the appearance and usefulness of the hand, or to prevent the extension of the hypertrophic process to the remaining portion of the hand or limb.

Elephantiasis.—Exceedingly rarely is the hand or upper extremity the seat of true elephantiasis, that is, hypertrophy from lymph stasis, especially due to occlusion of lymph vessels by filaria, though a few cases are said to have been observed. Elephantiasis and the idiopathic hypertrophy just considered have points of resemblance and have been confounded with each other in some instances, but there is doubtless a definite pathological distinction between the two conditions. The treatment is the same as that of congenital dactylomegaly and of elephantiasis.

An elephantiasiform hypertrophy sometimes follows healing of lupus vulgaris on the hand, from chronic œdema produced by occlusion and obliteration of lymph and blood-vessels, with tendency to recurrent dermatitis, cellulitis, and lymphangitis.

Gigantism.—In this condition the hand and fingers participate in the general enlargement of the body, but their development is not proportionally greater than that of the rest of the body.

Acromegaly.—In this rare condition the hands, along with the feet and bones of the head, undergo general hypertrophy, with, later, constitutional disturbances. It occurs rather more commonly in females, and usually begins to develop at the age of about twenty-five to thirty years. Etiologically and pathologically it is supposed to be usually associated with some morbid condition of the pituitary body. It is a chronic and slowly progressing condition.

In the upper extremity the lesions are chiefly confined to the hand and wrist, which are enlarged by a general hypertrophy of all the tissues, soft and hard. One of the first manifestations of the disease is an increase in thickness of the fingers, so that gloves and rings become too small. When the trouble is fully developed, the hand is enlarged generally, and is described as having a "spade-like" appearance. Its function and usefulness are unimpaired. The fingers are broad and sausage-shaped, and the terminal phalanges are not bulbous or larger than the rest of the digit. The nails are usually broad, flat, grooved, and friable.

Along with the hands the feet, face, and head are correspondingly affected. The results of treatment have not been very satisfactory.

Hypertrophic Pulmonary Osteo-arthropathy.—This is a rare condition in which the hands and feet, with the distal portions of the forearms and legs, undergo hypertrophy in association with chronic pulmonary, pleural, or bronchial disease, such as phthisis, tuberculosis, empyema, pneumonia, syphilitic and malignant thoracic disease, chronic bronchitis, etc., mostly conditions in which the arterialization of the blood is impaired. The condition is rare, only about sixty cases being recorded. Adults and males are affected most frequently, though children and females are not exempt. Usually the hypertrophic condition develops insidiously, gradually, and slowly, but in exceptional instances it has a sudden onset and rapid development, becoming well defined in the course of six or twelve weeks.

The hypertrophic condition consists in a general and symmetrical enlargement of the hands and feet and the distal extremities of the forearms and legs, other parts of the body being scarcely affected. In the members involved the bones are especially affected, being increased in length and thickness, partly by increased subperiosteal bone formation, partly from the development of wart-like bony nodules; the joints are also somewhat involved, from synovial effusion, erosion of articular cartilages, etc.; the soft parts are less implicated. In the upper extremity, the lower ends of the radius and ulna, the carpal, metacarpal, and phalangeal bones may all be involved. The terminal phalanges are usually markedly enlarged, giving the digits a club-shaped or drumstick appearance. The nails are much increased in size and very convex, both transversely and longitudinally, and arch over the ends of the fingers.

Pain, sometimes severe, is present in the hands in most cases, at least at some period in the course of the disease.

Among the features by which this condition can be differentially distinguished from acromegaly may be mentioned the association with pulmonary disease, the absence of any enlargement of the bones of the head, such as occurs in acromegaly, and the bulbous enlargement of the terminal phalanges and the shape of the nail, which are not manifested in acromegaly.

The essential pathological nature and cause of hypertrophic pulmonary osteo-arthropathy are not yet determined. The prevalent French theory is that the enlargement is produced by chronic inflammatory processes induced by toxæmic irritation. The condition probably has some relationship, and is even perhaps identical, with clubbed or Hippocratic fingers.

There is no definite treatment.

Hippocratic or Clubbed Fingers.—The term clubbed finger is employed to designate conditions in which the terminal phalanges or ends of the digits are enlarged and bulbous, that is, larger than the remainder of the fingers, giving them a club or drumstick shape. The fingers in hypertrophic pulmonary osteo-arthropathy and sometimes in myxœdema exhibit this condition. The term clubbed fingers is commonly used, and the term Hippocratic fingers is specifically used to designate a bulbous enlargement of the ends of the fingers, with a longitudinal curvature of the nail, that is occasionally present in chronic conditions in which the circulation is weakened, especially in pulmonary tuberculosis and heart diseases. The enlargement of the finger tips is brought about by a chronic state of or tendency to passive congestion, which occurs in these parts because, from their peripheral situation and distance from the heart, the strength of the circulation is here at a minimum. The condition can be treated only by attention to the general disturbance which causes it.

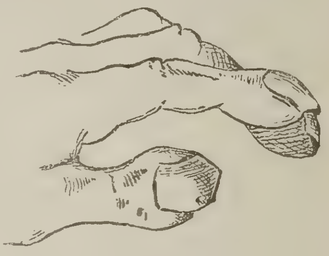


FIG. 2482.—Hippocratic Fingers. (Meillet and Richer.)

Myxœdema.—The hands and fingers share in the general enlargement of myxœdema, which it is unnecessary to consider generally here. There is no pitting on pressure, the fingers may be clubbed, and the nails are unaffected.

Syringomyelia.—In a very few cases of syringomyelia there has been observed a general increase in size of one of the hands and upper extremities from hypertrophy of all the tissues. It is possible that occasionally cheiromegaly may result from trophic influences in other morbid nervous conditions.

NEOPLASMS

of various kinds may develop upon the hands or fingers, but exhibit few features of special importance different from those manifested in other situations. Conditions more or less simulating tumors occur in various inflammatory, arthritic, tuberculous, syphilitic processes, etc. Aside from warts, this region is not particularly prone to the development of neoplasms. In some cases the tumors are of congenital and developmental origin, in others trauma exerts etiological influence, in many cases the cause is obscure.

The congenital tumors of the hand and fingers compose a group of cases in which the tumor is present at birth. Neoplasms of this class that have been observed are rudimentary supernumerary fingers, dermoid tumors and cysts, fibromata, lipomata, chondromata, and angiomata. Such congenital tumors are not common.

As already stated, *supernumerary fingers* are often of so rudimentary a structure that their digital nature is shown only by the presence of a small amount of osseous or cartilaginous tissue or a nail; such structures practically amount to tumors. These are usually attached by a soft pedicle and are most commonly situated on the ulnar margin of the hand or little finger. If we conceive such structures to be still more rudimentary, lacking all traces of bony or cartilaginous tissue or nail, we will have left simply tumors composed of fibrous tissue covered with skin, and having no distinct digital characteristics. Congenital tumors of this nature have been observed, often pedunculated and on the ulnar side of the hand, and in some cases are doubtless supernumerary digits of extremely rudimentary character.

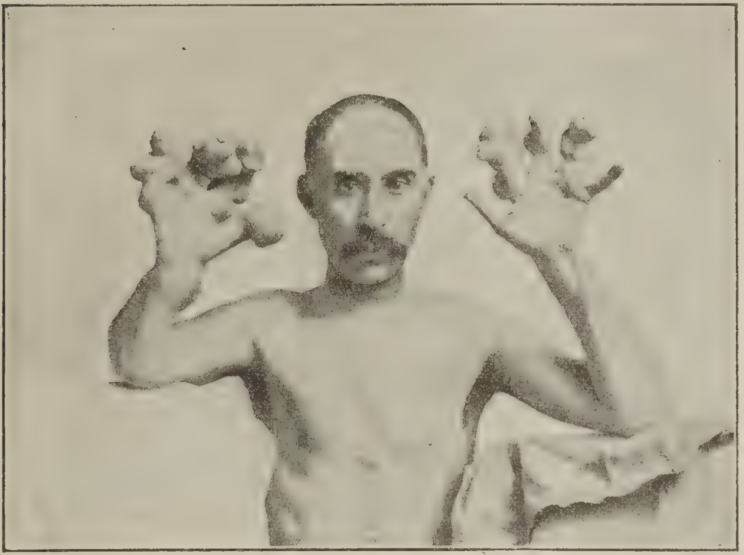


FIG. 2483.—Multiple Osteo-ecchondromata of Hands. (Whittaker.)

Dermoid Cysts or Tumors, congenital, containing epidermal tissue, hair, and sebaceous matter in their interior, are occasionally encountered in the region under consideration. Some of them are also perhaps supernumerary digits of very rudimentary and aberrant type.

Warts—the familiar verruca vulgaris—are very common on the hands and fingers, which are their favorite seats. They are especially common in childhood, occurring singly or in numbers. They consist of hypertrophied and elongated papillæ of the corium surmounted by thickened and horny epidermis. Among the methods of treatment may be mentioned cutting off the growth with knife or scissors and applying caustics—as silver nitrate, potassium hydrate, or chromic acid, solid or in solution —to the denuded surface.

Fibromata occur occasionally, situated in the subcutaneous tissues, or connected with tendons, periosteum, or bone.

Lipomata are rare in this situation. They may occur in connection with congenital dactylomegaly. They are usually diffuse, not circumscribed, and continuous with the subcutaneous tissue.

Chondromata are the commonest (aside from warts) of the benign neoplasms of the hand and fingers. Sometimes they are congenital, sometimes result from traumatism, usually arise without assignable cause. They occasionally develop in the soft tissues, but usually arise from the interior or the surface of the bones, the periosteum, or the joints. They may be firm or soft, may break down and ulcerate, and may ossify. They may be single or multiple, may involve one or several fingers, one hand or both hands. Often they attain a large size and occasion great deformity and disability, so that amputation may be required.

Osteomata and exostoses occur occasionally, arising especially from the bones or periosteum, and may occur in association with chondromata. *Neuromata* are said to have been observed in the hand. *Angiomata,* nævi, and erectile tumors sometimes occur in this situation.

Epithelioma develops in the skin of the hand, as in other situations. *Sarcoma* may attack the hand, originating especially in bone or periosteum; it occurs in its various forms, may attain great size, and may involve more than one finger.

The treatment of neoplasms of the hand and fingers must be guided by general principles and the circumstances of the case. Removal or excision of the tumor, or amputation if deformity is extreme, are the ordinary procedures. The malignant tumors require complete removal or amputation.

CYSTS

occasionally develop in this region. Dermoid cysts have been mentioned. Sebaceous cysts occasionally occur, sometimes induced by traumatism; cysts resembling wens in all respects even occur on the palmar surfaces, which are free from hair and sebaceous glands. Aneurisms and hydatid and cysticercus cysts rarely occur here. Ganglion will be considered subsequently.

TRAUMATISMS AND INJURIES.

From its exposed situation the hand is very subject to injuries of external origin, mechanical, chemical, thermic, etc. Mechanical traumatisms cause wounds, contusions, sprains, dislocations, fractures. Various chemical substances produce irritation, inflammation, ulceration, or necrosis. Heat causes burns and scalds; cold produces frost bite.

Wounds of all kinds—incised, lacerated, contused, punctured, gunshot—are of common occurrence. Not infrequently portions of fingers or entire digits are cut or torn completely off. The treatment is that of wounds in general, the chief objects aimed at being hæmostasis, asepsis, coaptation. Aseptic wounds heal well and rapidly in this situation, but if infection occurs healing may be very slow; asepsis is therefore highly important, especially after bites of animals. Tendons and nerves, if severed, should be carefully sutured to avoid subsequent impairment of function. The hand should be immobilized while healing.

When portions of the fingers are entirely cut off or hang by a small neck or shred of tissue, there is some hope of obtaining complete reunion of the severed portion. The parts should be well cleaned and sutured nicely together. Well-authenticated cases are on record in which a part of a finger completely cut off has perfectly reunited to the stump when sutured back in place, so that an attempt should at least be made to save the finger in all such cases. A case has been reported in which the hand was almost severed from the forearm at the wrist, all the blood-vessels and muscles and most of the

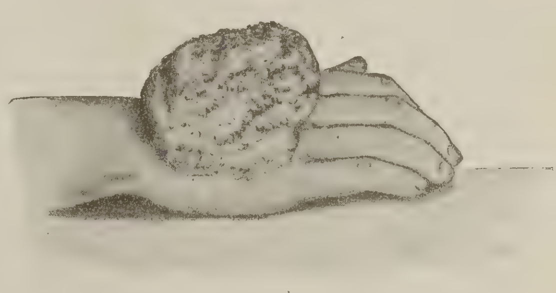


FIG. 2484.—Epithelioma of Hand. (B. F. Curtis.)

bones being divided, leaving only the ulna and a small portion of skin intact; even in this case good union was obtained with re-establishment of the circulation and function of the hand. Such cases illustrate the advisability of conservative treatment of wounds of the hand, and of the attempt to save as much of the member as possible.

Contusions and crush injuries of the hand and fingers are very common, and exhibit all gradations from slight bruises to cases in which the hand is crushed and lacerated into a shapeless mass, as in machinery injuries. The treatment is to be guided by the circumstances, but it should be as conservative as possible, and it should be remembered that this region possesses great reparative power if uninfected. Complete destruction of the ends of the fingers by crush injuries, the nail and all the soft tissues to the bone being destroyed, may be followed by regeneration so complete that scarcely any trace of the injury will be perceptible. Unlike the lower extremity, lost parts of the hand or upper extremity cannot be satisfactorily replaced by mechanical apparatus, so that in injuries every attempt should be made to save as much as possible of this useful and unreplaceable member. Parts should not be amputated unless or until it is evident that repair is impossible.

Foreign bodies, like bullets or splinters lodged in the member, *bites* and *stings* of insects, and other poisoned wounds, etc., should receive the customary treatment, infection being especially guarded against. *Sprains* and *dislocations* will be considered in connection with the affections of the joints. *Fractures* of the metacarpal or phalangeal bones are simple of treatment, requiring reduction and immobilization.

Burns and scalds of the hand are very common, causing superficial dermatitis, ulceration, or more or less necrosis. If the destruction of tissue is extensive they are exceedingly apt to be followed by deforming and disabling cicatricial contractions.

Frost Bite.—From their small size, exposed situation, and distance from the circulatory centres, the fingers are often frozen, being exceeded in their liability to this accident only by the ears and toes. Frost bite is apt to cause complete necrosis of the tissues involved, though the gangrene may be slow, even weeks, in attaining its full development. The frozen parts should at first be thawed out very slowly, as by the use of cold water, in order to avoid inflammatory reaction. The subsequent treatment is that of the necrosis which may supervene, removal of the sloughs by poulticing, caustics, or excision, asepsis, and protection of the resulting ulcer; and if the gangrene is extensive enough and when the limits of the necrotic process are demarked, amputation, preserving as much viable tissue as possible.

INFLAMMATORY CONDITIONS

in the hand and fingers may arise from mechanical, chemical, or thermic irritation, or from trophic impressions in some nervous diseases; but they are chiefly produced, and to a more serious degree, by infection with the pyogenic and other micro-organisms.

Inflammation in the hand may occur in any part of the member; it may affect special tissues or structures exclusively (as the joints, tendon sheaths, bones, etc., to be considered subsequently), or it may involve various contiguous tissues. Inflammation affecting the tissues of a digit in general is termed dactylitis, though this designation is chiefly employed in connection with tuberculous and syphilitic dactylitis. Lesions of trophic origin will be considered in connection with the corresponding nervous disorders. Inflammations of infectious origin are intimately associated with the other pathological processes presented by the infection, so that often practically the two can scarcely be separated. The treatment of simple inflammations must be guided by the circumstances of the case, the cause, and the associated conditions.

INFECTIOUS AND PARASITIC CONDITIONS.

From its exposed location the hand is especially liable to infections. Pathogenic micro-organisms are very easily introduced through wounds, often so minute as to escape notice at the time, through blisters, through bites and scratches of animals and insects; a considerable variety of infections may thus become established. Much the most frequent of the infectious conditions of this member are those of suppurative nature. A small proportion of infections are represented by tuberculosis, syphilis, gonorrhœal lesions, leprosy, scabies, tinea, and others.

SUPPURATIVE AND RELATED INFLAMMATORY CONDITIONS, caused principally by the pyogenic staphylococci and streptococci, are the commonest of the infections of the hand, and occur in a variety of forms, as infected wounds, cellulitis, erysipelas, and abscess. In the initial stages of these conditions the morbid process may be purely inflammatory, suppuration setting in later. In some mild cases the morbid process does not pass beyond the stage of simple inflammation, being arrested before suppuration occurs. In some forms of erysipelas also typical suppuration does not occur.

The simplest form of pyogenic infection is that exhibited by *infected wounds*, in which the tissues adjacent to the injury are inflamed or suppurating.

In more severe cases the infection extends to tissues more distant from the wound. The treatment is the same as that of similar conditions elsewhere.

The terms cellulitis and erysipelas are in certain cases used interchangeably. Three forms may be distinguished —indurative, exudative, and suppurative.

Indurative Erysipelas is the form characterized by a slightly elevated, red, indurated, inflamed area on the skin, advancing into healthy tissue. This is the form commonly encountered in facial erysipelas; it occasionally occurs on the hand, originating from minute wounds, and only exceptionally proceeds to suppuration. Its treatment is that of the facial form, a variety of procedures being available, as cold applications, tincture of iodine, painting with solution of silver nitrate, injections of antiseptics, moist antiseptic applications, sedatives and emollients, etc.

Exudative Cellulitis is an infectious condition that often involves the upper extremity. The infecting organism gains entrance at a wound about the fingers or hand, often insignificant and unnoticed. The earliest symptom, often overlooked, is a faint red and inflamed streak, perhaps a little tender, extending from the point of infection up the arm; this is caused by an inflammation of the subcutaneous lymphatic channels, up which the infection rapidly extends. Next a large accumulation of serous fluid occurs in the subcutaneous tissues, causing a great distention and swelling of the fingers, hand, forearm, and more or less of the entire upper extremity. This lasts for several days before it subsides, and is accompanied by fever and much pain (from the tension). Sometimes the case proceeds to a general phlegmonous cellulitis, often resolution takes place without suppuration. The treatment consists in disinfection of the original focus of infection if it is discoverable; immersion of the swollen parts in ice water, for hours and even days to mitigate and arrest the process; multiple incisions through the skin if necessary to relieve tension and pain and allow escape of fluid; application of moist antiseptic and sedative applications; tight bandaging to keep the swelling down, etc.

Suppurative Cellulitis (phlegmonous erysipelas, abscess, etc.) is a suppurative inflammation of the connective tissues beneath the skin. It may be diffuse or circumscribed. It may involve an extensive area, with considerable danger to life, or it may be localized and confined to a small region (abscess). The portal of infection may be obvious, or the origin may be quite obscure. The process begins with a simple inflammation, gradually proceeding to suppuration; or in mild and abortive cases the trouble may at no time proceed as far as definite suppuration. The treatment, in general, is that of such conditions generally: in the early stages attempts to abort the process and avert suppuration by cold, application of tincture of iodine, and the like; when suppuration is manifestly inevitable it may be encouraged by poultices and warm applications; and as soon as suppuration fairly sets in, free incision and open treatment of the abscess. Suppurative processes in the hand and fingers are apt to run a very slow and protracted course before final recovery, this member not appearing to have rapid and vigorous reactive and reparative power in such conditions.

No part of the hand is exempt from suppurative inflammations or abscesses, but certain regions are so subject to these infections and exhibit such special features that a few special forms of the inflammatory process are plainly distinguishable and require special attention, namely, paronychia, whitlow, palmar abscess.

Boils and carbuncles may occur in this situation, but the hand is not a favorite seat of these lesions.

Paronychia (Infectious).—The ordinary acute paronychia, popularly termed "run-around" or "ring-around," is an inflammation, sometimes running on to suppuration, of the tissues at the sides and root of the nails. It is produced by the various pyogenic bacteria, which gain access at the root of the nail; there are also syphilitic and tuberculous forms of paronychia which are more chronic. The inflammation involves the cutaneous and subcutaneous tissues of the circumungual region, only one finger, as a rule, being affected at a time. At first the ordinary phenomena of inflammation are manifested —redness, pain, tumefaction. The pain and tenderness are not usually severe, but are sufficient to cause considerable annoyance and irritation. Many cases do not go beyond simple inflammation, but others proceed to suppuration, and in severe cases the nails may be cast off, and ulceration may ensue. While usually acute and of short duration, the course of paronychia may sometimes be subacute and prolonged. The inflammation is apt to be more severe and more prolonged in those of generally lowered constitutional condition or with specific taint. Paronychia is a common affection.

In the early stages, with the view of checking further progress of the inflammation and to relieve pain, applications of iodine, cold, emollients, sedatives, or poultices may be employed. To promote suppuration when inevitable, poultices are useful, and when pus formation is established free incision should be practised and the lesion treated like ordinary abscesses. The trouble usually yields readily to treatment. In cases of debility or specific taint constitutional treatment may facilitate healing.

Whitlow, Felon, or Panaritium (panaris), is a localized suppurative inflammation of the tissues of the palmar portions of the digits. Abscess may affect the dorsal tissues, but is much more frequent in the palmar regions of the fingers, where it presents special features. As regards pain, duration of disability, and loss of tissue, whitlow is a condition of no little gravity. Very often there is no perceptible wound by which the infecting bacteria gained entrance. Sometimes the condition arises after a slight bruise, blister, or other traumatism unaccompanied by any solution of continuity of the surface skin, a slight contusion of the tissues probably producing a local lowering of vitality and lessening of resistance that determine the development of infection at the point. A lowered constitutional condition may sometimes be a predisposing cause. Destructive processes in the fingers, often called whitlows, are generated by trophic influences in certain nervous affections, notably syringomyelia, but these have rather a necrotic character than the infectious nature of true whitlows. Any of the phalanges of the finger may be affected, more frequently and often more seriously the distal phalanx. Only one finger is ordinarily involved at a time, and whitlow is a quite common affection.

Three groups of tissues may be involved in the inflammation—the skin and subcutaneous tissues, the periosteum and bone, and the tendons and their sheaths. The inflammatory process may originate in any of these tissues, but usually extends from one group to another. The course of the disease varies according to which phalanx is affected.

The *distal phalanges* are somewhat more frequently affected than the middle or proximal ones. If the inflammation begins in the superficial tissues the skin shows the signs of inflammation—redness, swelling, pain. If the infective process starts deeper, the skin will not itself be red or inflamed, but the subcutaneous tissues will be œdematous from the inflammatory exudate, and the finger at this point will be tense and swollen and the seat of severe throbbing pain. In the distal phalanges there are no tendons and sheaths to enter into the case, but the subcutaneous fibrous tissues are intimately united with the periosteum, and inflammation of the subcutaneous tissues is almost certain to extend to the periosteum and bone, especially if thorough incision is not early practised. This involvement of the bone in the inflammatory process is what renders whitlow in the distal phalanx a rather serious condition. At first the morbid process is purely of inflammatory nature, but very early suppuration develops. Osteomyelitis sets in, and the phalangeal bone becomes carious and necrotic. The course of the trouble is exceedingly slow and protracted, and weeks often elapse before healing is complete.

The fingers possess quite slight resistance and reactive powers against deep-seated suppurative processes, perhaps from the relative circulatory weakness of these distal members. Pain is marked, often excruciating. The tissues at the height of the process are boggy and infiltrated with serous and purulent fluid, and the inflammation tends to extend proximally. Owing to the frequent deep situation and confinement of the infected area, the inflammation is apt to extend deep and far, causing great destruction of important structures before it will make an opening spontaneously through the skin. Granulation is slow to develop, but when well established the sinus is in a healing condition and on the way to obliteration.

Whitlows involving the *middle* or *proximal phalanges* are rather less common and generally less serious and protracted than in the distal phalanx. In these situations the tendinous structures are interposed between the subcutaneous tissues and the periosteum and bone, and to a large extent protect the latter from involvement. The escape of the bony structures from inflammation considerably mitigates the severity of the case. The morbid process readily extends along the tendons and tendon sheaths, and from destruction of their tissue or the formation of adhesions may cause considerable permanent disability and impairment of function. Aside from the special conditions offered by the presence of the tendons and the partial protection of the bone, the clinical features of whitlow in the two proximal phalanges are much the same as in the terminal phalanges. The inflammation may begin deep in the tissues, the more superficial structures being œdematous and swollen, and the surface not especially reddened. The infection may extend greatly in the tendon sheaths if an opening is not made in time through the overlying tissues. There is special liability to extension of inflammation along the tendon sheaths of the thumb and little finger into the palm. Pain is severe and healing is slow.

In treatment of whitlows, at their very inception an attempt may be made to abort the inflammation by tincture of iodine, application of cold, or subcutaneous injections of antiseptics like phenol. Such measures will not often be successful, and if the infective process continues to advance, radical treatment should be early adopted. Deep and thorough incision into the inflamed tissues is then necessary. Mere incision through the skin is not sufficient unless the trouble is all superficial; the opening must be carried down into the focus of infection. To secure thorough opening, therefore, in the distal phalanx the incision should be carried down to the periosteum; in the other phalanges incision to the tendinous structures will usually be sufficient. Free exposure of the affected region relieves tension and pain and provides a sort of safety vent, tending to prevent the further deep extension of suppuration. All fragments of necrotic bone should be removed, and curetting may be necessary. Poultices are useful both before and after the incision is made, to promote pus formation, relieve pain, and stimulate granulation. Drainage should be provided for, and the incision not allowed to close prematurely. Packing with iodoform gauze affords drainage and stimulates healing. Anodynes to relieve pain will often be required, and in debilitated patients general tonic treatment is indicated. Healing must be expected to be very slow, and some permanent deformity or impairment of the motor powers often follows.

Palmar Abscess.—Abscesses in the palm of the hand often involve the sheath of the flexor tendons in this situation, either primarily, or by extension from the digital tendon sheaths or from the subcutaneous tissues and fascias of the palm. The anatomical arrangement of the sheaths of the flexor tendons in the digits and palm is an important factor in palmar abscess. In the palm is a large synovial sheath common to the flexor tendons; this is continuous with the sheath of the tendons belonging to the thumb and little finger; but the flexor tendon sheaths of the index, middle, and ring fingers are closed at their proximal ends, and are not connected with the large common sheath in the palm. Consequently inflammation of the tendinous structures of the thumb and little finger can easily extend into the large palmar tendon sheath, and vice versa, while in the other three digits inflammatory processes do not extend from digits to palm. In whitlows of the thumb and little finger special care should therefore be taken to prevent extension into the palm. The inflammatory process may extend widely, especially if not adequately treated, involving more or less of the tissues of the entire hand, even to necrosis of the metacarpal or carpal bones. Palmar abscess is manifested by swelling, severe pain, heat, constitutional disturbance, fever, etc. It is quite a serious condition, and may result in more or less stiffening of the fingers, permanent injury of the tendons, and impairment of the motor functions of the hand; even death may occur from exhaustion, general sepsis, or hemorrhages.

The main feature of treatment of palmar abscess consists in early and free incision, so as widely to expose the inflamed parts. Care should be taken to open the main suppurating foci, and not to stop with opening into small secondary sinuses or superficial œdematous areas. Radical incision relieves tension and pain and localizes the process so as to prevent further extension. Longitudinal incisions in the palm, along the middle line of the metacarpal bones, can be freely made beyond the level of the web of the thumb without interference with the digital vessels or palmar arches. Aside from the special points mentioned and the greater area involved, the clinical features and treatment of palmar abscess and of whitlow are much the same.

TUBERCULOSIS.—The hand and fingers are subject to tuberculosis like other parts of the body. Infection may arise not only in the usual way, by internal conveyance of the bacilli, but also by direct inoculation through slight wounds from contact with external infectious material, as in the case of persons whose occupation necessitates the handling of diseased and dead tissues, like physicians, nurses, butchers, cooks, cattlemen, tanners. Notwithstanding this exposure to external infection, tuberculous lesions of the hand and fingers are not common. The bones, joints, tendon sheaths, and skin are the structures chiefly affected.

Tuberculous osteomyelitis or osteitis, with enlargement, chronic suppuration, sinus formation, caries, necrosis, loss of considerable osseous substance, and the usual phenomena of this condition, may involve any of the bones of the hand, sometimes primarily (so far as the hand is concerned), sometimes secondarily by extension from a lupus vulgaris, occasionally by extension from a tuberculous joint. Tuberculous arthritis affects by preference the larger joints of the body, though the wrist joint is sometimes affected; tuberculosis of the wrist and joints of the fingers more often arises by extension from foci in the neighboring bones or skin than primarily. Chronic tuberculous inflammation of the tendon sheaths (see below, p. 516) in the forearm and hand may arise, either primarily or by extension. In all these cases the course of the disease is protracted and chronic, though recovery may ensue. Sometimes the tuberculous involvement of the hand occurs in association with tuberculosis elsewhere, as in the vertebræ or lungs; in other cases the infection may make its first appearance in the hand. From the hand the disease may extend to the lymphatic glands of the arm, or general infection of the body may occur; in some cases the system may escape. Great deformity of the hand may follow after healing of the lesions, from cicatricial contractions and loss of tissue.

The chief clinical forms in which tuberculosis of the skin appears in the hand are lupus vulgaris and tuberculosis verrucosa.

Lupus vulgaris affects the face most frequently, but in a considerable proportion of cases attacks the extremities, including the hand and fingers. The dorsum of the hand is the locality chiefly affected, the disease only very rarely beginning in the palm. The disease occurs or begins chiefly in childhood. It runs a very slow and chronic course, though at times it makes rapid progress. Lupus vulgaris sometimes originates directly from external inoculation, but the infecting bacilli are usually derived from sources within the body, and the condition is often secondary to other tuberculous lesions. Clinically the affection arises from soft, brownish-red, painless nodules which develop in the corium singly or in coalescent aggregations and cause a slight projection above the cutaneous surface. The nodules may run their course as such, and undergo involution and absorption, leaving a superficial desquamating area and a sunken cicatrix; or they are very apt to break down and form shallow ulcers; or the affected tissues may proliferate in exuberant fungoid granulations. After pursuing an exceedingly protracted course for months or years, the ulcers may heal, and great cicatricial contraction or elephantiasiform enlargement may result. In the hand the tuberculous process may extend from the skin downward to the subcutaneous tissue, tendons, and bones, causing widespread involvement of the parts (as in tuberculous dactylitis), with suppuration, abscesses, sinuses, caries, and necrosis of bone. After healing from such a condition great deformity is apt to result, the fingers being distorted, mutilated, twisted, thickened, ankylosed, etc., from cicatricial contractions and loss of tissue.

Tuberculosis verrucosa is a form of cutaneous tuberculosis differing in some of its clinical features from lupus vulgaris. It arises chiefly from direct external inoculation of the skin with the tubercle bacilli, and hence occurs mostly in adults whose occupation exposes them to the handling of infected tissues or other material. The hands and fingers, especially their dorsal surfaces, are therefore the commonest seats of tuberculosis verrucosa, though other parts of the body, as the elbows and knees, are also subject to it. The essential lesion of tuberculosis verrucosa begins as a papule in the corium, which becomes pustular, then breaks down and forms a small ulcer, upon which papillary growths develop, and after some time become covered with a horny mass. The characteristic feature of fully developed verrucose tuberculosis is the tendency to horny or warty papillary proliferation. The disease extends slowly from a centre.

The simplest form of the trouble is the *verruca necrogenica,* also called "post-mortem wart" and "anatomical tubercle," which is a small nodule found on the fingers or hand of persons exposed to local inoculation, as physicians or nurses engaged in clinical or autopsy work.

Fully developed tuberculosis verrucosa is similar in nature, but of greater extent. In this condition there are slightly elevated horny, warty patches on the skin, varying in size from small areas to large plaques covering the entire dorsum of the hand and even extending over on the palm. The patches are aggregations of warty nodules and slowly extend at the periphery. They have an erythematous border, inside which is a zone of pustules; the centre of the patch is occupied by an aggregation of warty tubercles covered with crusts and horny material. There may be erosions and fissures, but there is little tendency to ulceration. The centre may undergo resolution, leaving a central cicatrix surrounded by a disease ring. The course of the disease is very slow and chronic, sometimes continuing for years. Usually the general condition is not impaired, and the lesion is not ordinarily followed by serious results; general tuberculosis may, however, originate from the cutaneous infection.

In both lupus vulgaris and verrucous tuberculosis the essential lesion is tubercle formation in the corium, and in both tubercle bacilli have been demonstrated.

In addition to these two types of cutaneous tuberculosis other clinical forms of tuberculous dermatitis and cellulitis may occur. Chronic paronychia of tuberculous origin has been observed; and some cases of "malignant paronychia," in which there is extensive ulceration and a protracted and severe local condition, are supposed to be of tuberculous nature. An inflammatory tuberculous tumor, not of warty nature, has been known to follow a slight wound on the hand caused by the thumb nail, in the case of a physician who at the time was treating two cases of tuberculous laryngitis (Schamberg).

Tuberculous dactylitis, or tuberculous inflammation of various tissues of the digits, though an uncommon condition, presents some distinctive features. It may arise as a secondary extension from lupus vulgaris in the vicinity as already stated, but the more typical cases originate in tuberculous osteomyelitis of the phalanges. Tubercle formation begins in the marrow of the phalangeal bones, especially near the articular ends; the cortical bone becomes gradually involved, while new bone is simultaneously formed by the periosteum. In this manner the phalanx assumes a characteristic fusiform shape, enlarged at its middle. Later, the process may extend to neighboring tissues, joints, and fibrous structures, and there is usually a tendency to suppuration and sinus formation. Caries and necrosis of the bone is apt to follow, and from the destruction of a part of or even an entire phalanx, deformity results after healing, especially shortening of the finger. The skin is thickened, tense, and may be pale, red, or purple. Pain is slight; the affected part may be hard or soft. The disease occurs especially in childhood, and often in association with tuberculosis elsewhere, as in the vertebræ, or there may be a family history of tuberculosis. The disease is very slow and chronic in its course. Recovery from the local trouble may follow, often with deformity; or general tuberculosis may ensue. One digit alone may be affected, or a number (not necessarily adjacent) may be successively involved. The proximal phalanges are apt to be the ones affected.

Tuberculous dactylitis is quite similar in its clinical manifestations to syphilitic dactylitis, and has often been mistaken for the latter. The history (personal and family), the effects of specific treatment, etc., must be taken into account in making the diagnosis. The enlargement of the phalanges is more spindle-shaped in the tuberculous form, more spherical in the syphilitic form. The condition may also resemble whitlow, chondromata, exostoses, sarcoma, and hypertrophic conditions; but the history, the course of the case, the tendency to suppuration, and other clinical features usually permit ready differentiation from these conditions. As to prognosis, a protracted course of the disease is to be expected, but recovery often results and may be usually expected if general tuberculosis does not occur.

The *treatment* of tuberculous lesions in the deeper tissues of the hand is the same as that of such conditions in general—constitutional treatment (cod-liver oil, arsenic, etc.), opening of suppurating foci, curettage, injections of iodoform emulsions, etc. In the cutaneous forms of the disease vigorous local treatment often effects a cure. Curetting is very useful for ulcerating and granulating surfaces, in conjunction with caustics like silver nitrate, arsenic, and salicylic-acid preparations. Nodular and warty lesions are well treated with thermo- or galvanocautery or puncture. Small areas may be excised, but cicatricial contraction or recurrence of the disease in the scar may follow; skin grafting may be useful treatment for ulcers following excision. Scarification, in crossing series of close parallel lines, has been highly recommended, but requires repeated séances and a long time.

SYPHILIS.—Like other parts of the body, the hand and fingers are subject to various manifestations of syphilis, both inherited and acquired forms of the disease; a few special features are exhibited in this region. The chief syphilitic lesions encountered on the hand are the chancre, various syphilides, syphilitic paronychia, syphilitic onychia, gummata and inflammatory processes in the deeper tissues, syphilitic dactylitis.

The fingers and hand are occasionally the seat of the initial *chancre*, the primary inoculation taking place at this point not infrequently in physicians from exposure to the infection in the course of clinical work, or in others, not innocently, from libidinously handling the genitals. The inoculation is apt to take place about the nails, though the chancre may be situated on other parts of the hand, and may resemble paronchyia or whitlow. The chancre is usually red, thickened, elevated, indurated, and circumscribed, but ordinarily does not show much tendency to ulceration. Its course is slow. It is followed by enlargement of the epitrochlear gland, and often of the axillary glands.

Most of the varieties of *syphilides*—macular, papular, vesicular, pustular, tubercular—may affect the skin of the hands. The palms are quite favorite seats for the development of many syphilides, especially the papular and squamous forms, and exhibit a special tendency to desquamation of the lesions. The dorsum of the hands, on the contrary, is comparatively quite exempt from most forms of cutaneous syphilis; the ulcerating tubercular syphilide, however, frequently involves the back of the hand. The moist syphilitic papule may affect the interdigital angles.

Partly owing to its thick epidermis and marked desquamating tendency, the palm (with the sole) exhibits a special form of syphilide, the palmar (and plantar) syphilide. The lesions of this condition consist of irregular patches, only slightly elevated, covered with scales, beneath which is the dull red infiltrated corium. The margins of the patches are especially scaly. The patches may coalesce, forming serpiginous areas, and deep fissures into the corium may develop. Sometimes instead of desquamating the epidermis becomes hard and horny. Subjective symptoms are ordinarily absent. The lesions may occupy only a small area, or may extend over the entire palm, only rarely proceeding to the dorsal surface or beyond the wrist. They may develop early or late in the course of syphilis, are very chronic in their course, exceedingly obstinate and resistant to treatment, and show marked tendency to recurrence.

Syphilitic Paronychia, or involvement of the tissues about the nails (of fingers or toes), exhibits three chief types, a dry or corneous, an inflammatory, and an ulcerative form.

Dry or Corneous Syphilitic Paronychia, the commonest form, is characterized by a horny thickening or proliferation of the circumungual epidermis, with repeated exfoliation. It begins as a small, hard, horny mass at the side of the nail, which increases in size, and may extend entirely around the nail or even invade the entire dorsum of the last phalanx. This thickened epidermis cracks and exfoliates, leaving the surface ragged and scaly. There is slight tenderness, and a yellowish-white color. The corium is more or less infiltrated, and in bad cases may be thickened, fissured, excoriated, and painful. The nails are only slightly affected. The process is very indolent and recurrent, and occurs in the secondary stage of the disease. Several fingers are usually affected successively.

Inflammatory Syphilitic Paronychia begins as a papule or nodule, usually at the side of the nail, sometimes over the matrix, which pursues a very slow course without active inflammation or tendency to suppuration or ulceration, and disappears by absorption. The affected area is hard, dusky red, slightly tender. Onychia only exceptionally coexists. It is often confined to a single digit. It occurs in the secondary stage, especially in those of poor health and often in children with congenital syphilis.

Ulcerative Syphilitic Paronychia is a severe condition caused by a gummatous process, with necrosis, in the corium and subcutaneous tissues. It is a secondary or perhaps rather a tertiary phenomenon, and develops especially in severe neglected or debilitated cases of syphilis. It is often confined to a single finger, and is very chronic in its course. The lesion consists of an indolent ulcer with undermined edges, and surrounded by a raised dusky or red border. An abundant thin sero-purulent discharge is given off. From extension of ulceration to the matrix and nail bed, the nail becomes discolored, undermined, and loosened, and may be cast off. In severe cases the granulations become exuberant and fungous; the cast-off nail is perhaps embedded in their midst as an irritating foreign body; the tissues about the ulcer swell and become indurated; the entire dorsal surface of the phalanx may be invaded; and the digit may become clubbed. If the nail bed and matrix are destroyed no new nail will be formed when the ulcer cicatrizes.

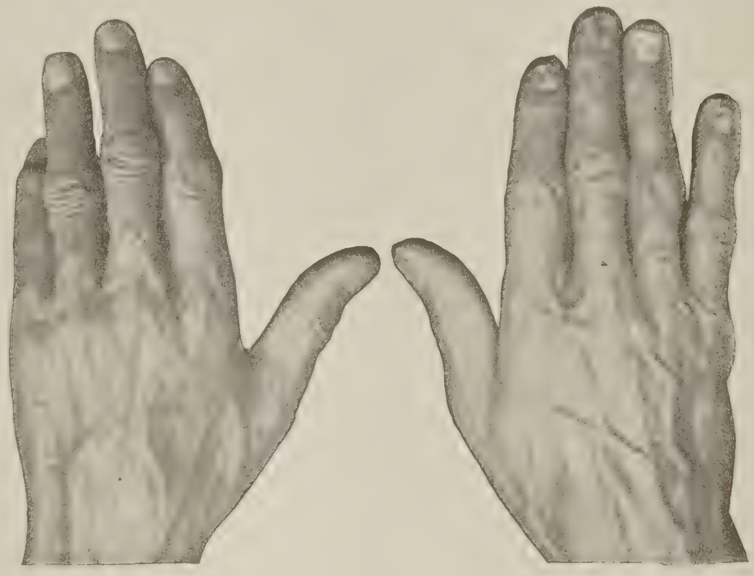


FIG. 2485.—Syphilitic Onychia. (Original.)

In the treatment of syphilitic paronychia, mercury alone or with the iodides is indicated. The iodides should be given especially freely in the ulcerative form. Local treatment should be followed according to the indications. The affected finger tips should be protected from irritation by finger-stalls, etc. In the ulcerative paronychia removal of the nail will often be desirable to prevent its acting as an irritant foreign body.

Syphilitic Onychia is an altered condition of the nails (of both fingers and toes) caused by defective nutrition and not of inflammatory nature. It occurs in the secondary stage of syphilis, both in the acquired and in the congenital forms, and sometimes appears in very young infants. Several nails are usually involved, either simultaneously or successively. It is only exceptionally associated with paronychia. All the forms pursue a very chronic painless course; ultimately recovery is perfect, and normal nails are reproduced.

Syphilitic onychia exhibits a number of different clinical varieties, as follows:

1. In the commonest form, "onyxis craquelé," in mild cases the nail becomes dull and lustreless, yellowish, brittle, and breaks easily on its edge; a similar condition may also occur in other chronic or debilitated conditions. In severe cases the nail in addition becomes marked by parallel ridges, and the free edge thickens and cracks and breaks easily, leaving an irregular broken margin. This condition is sometimes associated with dry paronychia.

2. In a second variety, the nail gradually and insidiously separates from the nail bed, beginning distally and extending toward the root of the nail. The separated portion is discolored. Usually the nail is only partially detached, but occasionally it is entirely cast off.

3. In another form the growth of the nail or formation of the nail substance is entirely or partially arrested. The boundary between the old nail and the new portion is formed by an irregular transverse line, which advances toward the end of the nail. The old nail becomes discolored, ridged, loosened, and finally drops off, and its place is taken by epidermis or by a thin and imperfect nail structure.

4. There is also a hypertrophic form, in which the nail becomes greatly thickened, with its surface dry, uneven, cracked and split, yellowish, dirty, unsightly.

Besides these varieties other forms of syphilitic onychia sometimes occur, similar in their general nature, all being conditions of lowered nutrition. The treatment consists in the administration of mercury (rather than iodide), with tonics, etc., in debilitated conditions. The finger tips should be protected by stalls, etc. The prognosis is good, and well-formed nails are almost always ultimately produced.

Gummatous and Inflammatory Processes may involve the deeper tissues of the hand and fingers in much the same way as in other parts of the body. The subcutaneous tissues may be the seat of gummata, which may break down and ulcerate; the palm, however, is almost exempt from this lesion. The tendon sheaths about the fingers are subject to gummata and to chronic and acute syphilitic inflammation. The bones and periosteum may be affected in various ways, in the form of gummata, periostitis, osteomyelitis, osteitis, caries, necrosis.

Syphilitic Dactylitis is a specific involvement of the tissues of the digits presenting distinctive clinical features, first definitely recognized by R. W. Taylor in 1871. It is one of the tertiary or late manifestations of syphilis, and occurs both in acquired and in inherited forms of the disease, and hence both in children and in adults. The fingers are oftener attacked than the toes. Any of the fingers may be affected, but the middle and ring fingers are said to be oftenest involved. One finger may be affected, or several, simultaneously or successively. The lesion consists essentially in a gummatous infiltration of the soft or hard tissues, which is apt to undergo necrosis and ulceration, together in some cases with chronic inflammation and secondary pyogenic infection. Two varieties of the disease are distinguished: (1) that in which the subcutaneous and ligamentous structures are primarily and chiefly affected, and (2) that in which the bone or periosteum bears the brunt of the disease.

1. In the first variety, or "syphilitic panaris," the subcutaneous fibrous tissues and the ligaments about the joints undergo gummatous infiltration. The dorsal sur-

EXPLANATION OF PLATE XXXI.

EXPLANATION OF PLATE XXXI.

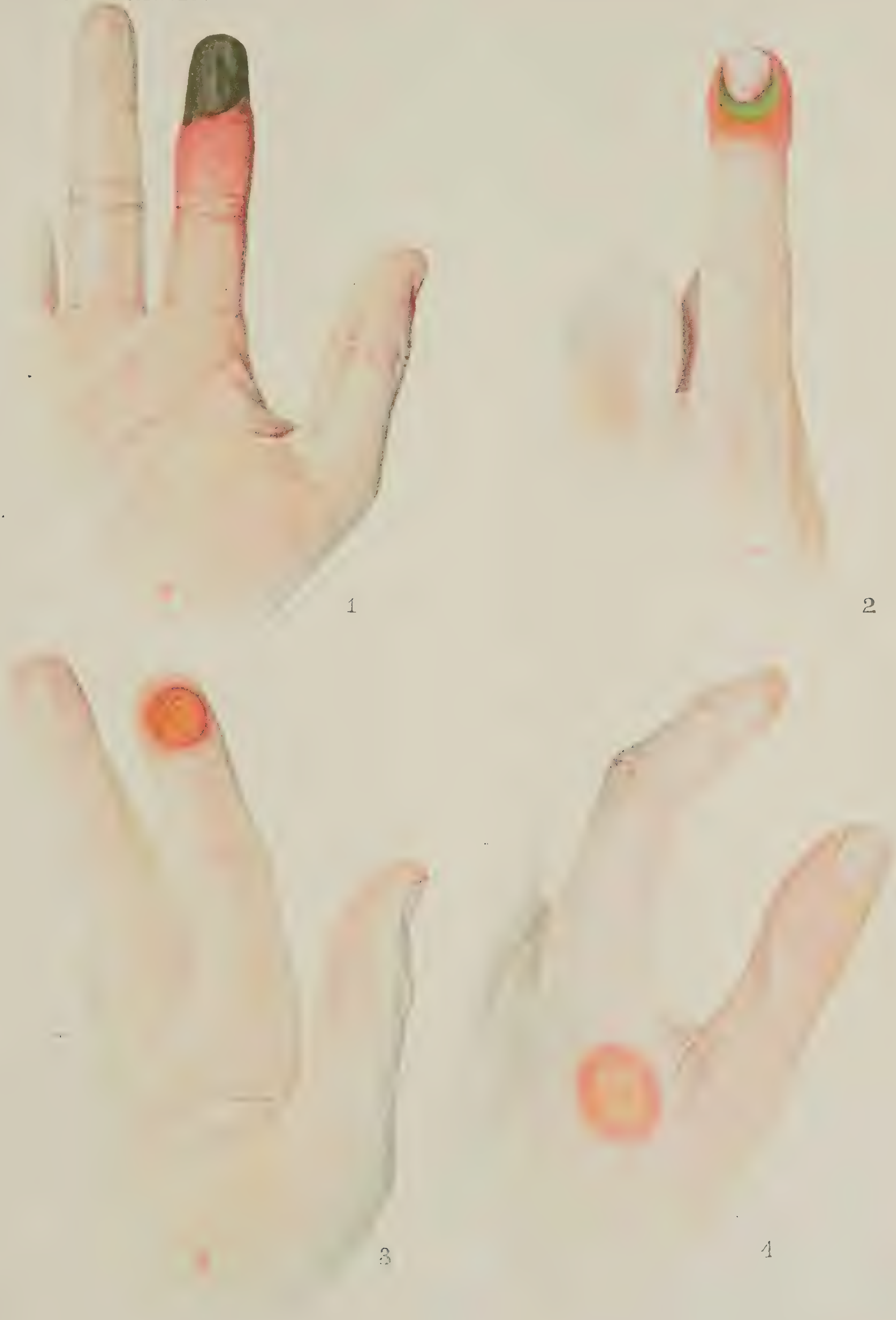
Fig. 1.—Raynaud's Disease, Showing Gangrene of the Finger. (Personal observation.)

Fig. 2.—Paronychia Caused by Infection with Bacillus Pyocyaneus. (Personal observation.)

Fig. 3.—Digital Chancre.

Fig. 4.—Tinea Circinata on the Hand.

(Illustrations drawn, from cases observed by Dr. J. B. Nichols, by H. C. Macatee, M.D., of Washington, D.C.)



DISEASES OF THE HAND

(Illustrations Drawn by H. C. Macatee, M. D., from Cases Observed by Dr. J. B. Nichols.)

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faces are rather more liable to this form than the palmar surfaces, and the proximal phalanges are especially affected. The parts affected increase in size and are tense and hard, or soft and semifluctuating. The overlying skin is purplish or violet in color. The gummata may break down, but do not tend to suppurate. The disease process in the ligaments sometimes extends to the articular structures beneath the synovial membranes, the articular cartilages, or bone; but the joint usually escapes serious involvement. The course of the affection is very chronic and nearly painless, and it is sometimes very resistant to treatment and tends to recur. This condition may be distinguished from gout, acute rheumatic arthritis, or whitlow by its chronic painless course; from rheumatoid arthritis by the location of the initial lesions in the joints, the early deflection of the phalanges, and the non-discoloration of the skin, in the latter, as well as by the concomitant symptoms and history. The prognosis is good, and recovery with a useful finger may be ultimately expected, unless the joints are seriously damaged.

2. In the second and more typical form of syphilitic dactylitis the osseous tissues and periosteum are primarily and especially affected. In a syphilitic child or adult, with or without other syphilitic manifestations, a phalanx in one or more fingers begins to enlarge. The process begins as a gummatous growth, causing marked enlargement, and may be associated with inflammatory conditions (osteitis, osteomyelitis, periostitis). If the marrow cavity is first involved, the symptoms are more acute, pain is more severe, the increase in size more rapid. In connection with gummatous infiltration of the hard bony substance, osteitis occurs, either rarefying osteitis, with destruction of the bone, or, later, formative osteitis causing new formation of bone. Gummatous deposits in the periosteum may produce multiple small tumors.

In typical cases there is marked spherical or fusiform enlargement of the affected phalanx. The soft parts are stretched; the skin is purple, violet, livid or red, shiny or dull. When the gummatous enlargement is advanced the new tissue breaks down into a fluid discharge or cheesy mass; ulceration takes place; secondary infection with the ordinary pyogenic germs may occur, and suppurating sinuses are formed. Extension to the joints may follow, producing synovitis, arthritis, or general gummatous involvement and disorganization of the articlar structures. Pain varies, frequently not being marked, but sometimes severe, often worse at night. Usually only one phalanx in a digit is affected, sometimes more. The proximal phalanx is the one most often invaded; not infrequently the metacarpal bone suffers. The course of the disease is chronic, or often subacute.

After recovery the new tissue may entirely disappear, or permanent changes remain. Decrease in size, with alteration in length or thickness, may follow necrosis and destruction of bony substance; increased size may result from formative osteitis. Cicatricial contractions may supervene. Joints may be destroyed, or false joints may be produced (from non-union after necrosis of bone), constituting a very disabling flail joint. Rarely ankylosis results. The prognosis on the whole is favorable; involvement of a single phalanx without extension to the joint is apt to recover without bad consequences. Loss of substance, the formation of flail joints, ankylosis, or cicatricial contractions may impair appearance and usefulness, and often to a great degree.

The diagnosis of syphilitic dactylitis from tuberculous dactylitis has already been considered. From ordinary whitlow it may be differentiated by its less painful and more chronic course and development, and the history of the case. From cartilaginous and bony tumors it may be distinguished by its less sharp localization, the tendency to necrosis, ulceration, and suppuration, the history, and the results of specific treatment. From various hypertrophic conditions, the clinical course and features and the inflammatory and ulcerating phenomena of syphilitic dactylitis will enable the diagnosis to be made.

In the treatment of syphilitic dactylitis, the iodides, with or without mercury, should be vigorously administered, with tonics if indicated. Too much should not be done locally. Gummata should not be opened or removed, and amputation is contraindicated; but if suppuration sets in it should be treated on ordinary surgical principles, by opening of abscesses and sinuses, curetting, removal of necrosed bone, etc.

OTHER INFECTIONS AND PARASITES.—Infection of wounds with other than the ordinary pyogenic bacteria is liable, from its exposure, to occur in the hand, as in some post-mortem wounds, laboratory infections, infection with the gas bacillus, anthrax, glanders, rabies, tetanus, etc. Some of these infections are very malignant and grave, though fortunately uncommon. The morbid condition is manifested either locally or systemically, or in both ways. The local condition consists in an inflammatory process in the tissues adjacent to the wound, with clinical features varying according to the infective agent.

The systemic manifestations are of septicæmic, metastatic, or toxæmic character, and constitute the element of danger in these cases. In some conditions, as in rabies and tetanus, substantially the entire clinical picture is made up of the constitutional manifestations, there being practically no morbid condition at the point of original entry of the infection.

The treatment of infected wounds of the hand is the same as that of these wounds generally—efforts at local destruction of the infecting parasites and their toxins, and cure of the local inflammatory lesions, with appropriate measures to combat the general manifestations.

Gonorrhœa may affect the hand in the form of gonorrhœal arthritis of the finger joints, which are a rather favorite site for gonorrhœal rheumatism; also occasionally as a gonorrhœal thecitis or other inflammatory affection.

Leprosy affects the hands severely, especially in the anæsthetic variety. In tubercular leprosy the nodular masses may develop in the fingers and hand, though this member does not usually suffer so severely in this respect as other parts of the body; the nodules about the fingers may break down and ulcerate. In anæsthetic leprosy the hand is apt to become exceedingly deformed and mutilated, from disintegration and necrosis of the joints and bones, ulceration of the skin and soft tissues, atrophy of the tissues, and deflections and contractions of the digits. The fingers and even parts of the hand often drop off spontaneously. The parts are anæsthetic, and the course of the affection is very slow and chronic. Claw-hand sometimes occurs in leprous neuritis.

Scabies usually makes its first appearance on the hand, whence it is conveyed to other parts of the body. The sides of the fingers and the interdigital angles are the points particularly attacked. The *trichophyton* fungus frequently invades the back of the hand, in the clinical condition known as tinea circinata. At least three cases of *hydatid* or *cysticercus* cysts in the hand are on record: one in the subcutaneous tissues of the palmar surface of a proximal phalanx, one beneath the palmar fascia in the palm, one originating within a proximal phalangeal bone and causing distention of the phalanx to the size of an orange. *Elephantiasis* has been already mentioned.

NECROTIC CONDITIONS

arise in the hand as elsewhere. Two factors especially conducive to necrosis which are operative in the hand are the exposure of the member to traumatic accidents, and its distant circulatory position, which makes it not only suffer from relative circulatory weakness but also subjects it to the consequences of any impediment to the blood flow at any point between it and the body centres. In this respect the hand suffers less than the foot. Gangrenous and necrotic conditions in the hand arise from various causes, such as destructive violence or chemical action, burns, frost bite; from interference with the circulation, by occlusion of the blood-vessels, in thrombosis, embolisms, traumatisms, endarteritis obliterans (senile gangrene); in association with infectious and inflammatory processes, as in carbuncles and necrosis of bone; in trophic conditions like syringomyelia, leprosy; in ergotism, Raynaud's disease, diabetic gangrene, etc. The clinical features and treatment vary according to the circumstances.

ULCERS

occur in a considerable variety of conditions, as in syphilis, epithelioma, lupus vulgaris, from injuries, inflammatory and infectious processes, trophic influences, and after separation of the slough in gangrenous cases.

CICATRICIAL CONTRACTIONS

often occur about the hands and fingers, with consequences ranging up to extreme deformity and disability, the usefulness of the hand being at times almost completely destroyed. These contractions may develop after the cicatrization of wounds or ulcers of any sort, as after lupus or syphilitic ulcers, but especially after the healing of ulcers from burns. Protracted granulation favors the development of deforming cicatrices. The deformities produced are very various, consisting of palmar, dorsal, or lateral deflections of the fingers, acquired syndactylism, etc.

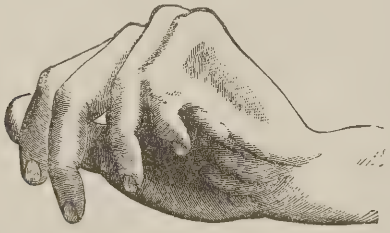

FIG. 2486.—Cicatricial Contraction in the Hand. (Gross.)

The successful treatment of these cases is quite difficult, as there is a strong tendency to recurrence after ordinary plastic procedures. As a prophylactic measure may be mentioned treatment of ulcers likely to be followed by contracting cicatrices in such manner as to shorten the period of granulation and healing, as by attention to asepsis or by skin grafting. Still, in slow-healing ulcers like those from burns there is little certainty of escaping later contraction. Even the keeping of the parts in a corrected or overcorrected position by splints or appliances is not very successful.

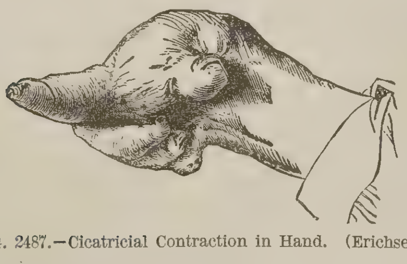

FIG. 2487.—Cicatricial Contraction in Hand. (Erichsen.)

The ordinary plastic operations sometimes succeed, but often do not secure permanent results. Among such procedures may be mentioned the lifting of a V-shaped flap, exsection of the cicatricial tissue, straightening of the parts, and final suturing of the wound in a Y-form. The Thiersch and Reverdin modes of skin-grafting for filling defects after dissecting out the vicious tissue are not very successful. A medicinal method of treatment of this and similar conditions, by the administration of thiosinamin, has been highly commended by a few, but has not come into general use. This drug is said to exert a selective disintegrating action on scar tissue; it is administered hypodermically, 0.1 to 0.2 gm. being injected deep into muscles (triceps or glutei) every three days, or by the mouth, 0.2 daily in capsules, kept up if necessary for weeks.

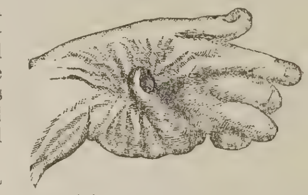

FIG. 2488.—Cicatricial Contraction with Backward Deflection of Little Finger. (Erichsen.)

The treatment recommended as most successful in these cases is a radical transplantation of a skin flap, one end of which is left with its original attachment and vascular supply intact until the flap is firmly united in its new position. The contracting scar tissues are divided and removed as much as possible, and the deformity is corrected. Into the gap thus left a flap of proper size, composed of the entire thickness of the skin, is brought and sutured. One end of the flap, affording the best vascular supply, is left unsevered from its original attachment until, after two to four weeks, the flap is well united in its new position. This flap can be taken in any convenient situation from the thorax, abdomen, or back, and the hand and arm bandaged in place until union is complete, when the flap is entirely detached from its original situation. In some cases it is probable that a similar flap could be taken from the dorsum of the hand and twisted around in position to fill a defect.

In intractable cases of great deformity amputation may be indicated, though it should be remembered that often a poor finger is more useful than no finger at all.

ACQUIRED DEFORMITIES.

The deformities to the acquirement of which the hand is subject are so various in their possible forms and diversities that they are hardly susceptible of useful classification. They may consist in loss of substance or parts, as from traumatisms, amputations, necrosis of bone or other tissue; in abnormal adhesions, in contractions of tissue, in deflections and distortions of fingers and hand from numerous causes, in nutritive alterations, in the results of occupation (occupation deformities). Most of the congenital forms of deformity may be duplicated by acquired conditions, as acquired acheiria, ectrodactylism, or hypophalangism from amputation or necrosis, acquired syndactylism from adhesions, acquired club hand or clinodactyly. The causes and nature of acquired deformities are so various that no general statements as to treatment can be made; each case must be managed according to its character.

EFFECTS OF OCCUPATION ON THE HAND.

The effects of an individual's occupation or habitual mode of life and environment may become marked by reactive consequences, structural and functional, upon various parts of the body, and especially upon the hand, since this member is so actively and constantly exposed and employed. The effects produced on the hand by occupation are not only of some clinical importance but are also of anthropological interest and medico-legal significance. An extensive study of the effects produced by a large number of occupations, especially from a medico-legal standpoint, made by M. Vernois, may be found in the *Annales de l'hygiène publique et de médecine légale*, 1862, 2d series, vol. xvii., pp. 104–190.

Among the many various factors which produce effects on the hand may be mentioned friction and pressure, as from the use of instruments and tools or the manipulation of machinery, which may have hypertrophic, irritative, or destructive consequences; frequent exposure to chemical substances, with irritant, caustic, emollient, staining, or other action; exposure to physical agencies, heat, cold, weather, sun; deposition of foreign matter;

the frequent repetition of slight traumatisms, "occupation insults," ultimately producing cumulative results. Any of the tissues and any part of the hand may be the seat of the alterations produced by occupation, and the changes may be either organic, with definite structural alterations, or functional and without anatomical changes. The particular changes set up vary in their site and nature according to the circumstances. While many avocations do not produce definite effects on the hand, others do produce distinctive and characteristic results.

Only a brief consideration of the general effects produced in the various tissues can be attempted here. For full and detailed information on the subject reference may be made to such works as that of Vernois, already cited.

The epidermis, from its superficial and exposed position, naturally exhibits marked effects from use. From continued pressure or friction it becomes very often hypertrophied, thickened, and hardened, especially on the palm, and either over the whole palmar surface or in circumscribed and distinctive localities (callosities) according to the site of pressure, as on the left finger tips of violinists. Or from exposure to water and other fluids, caustics, alkalies, acids, and similar strong chemicals, the epidermis may be softened, thinned, atrophied, or even entirely destroyed.

The cutis vera may from the action of irritants, etc., undergo inflammatory changes, or present erythema, blisters, pustules, ulcerations, fissures, cracks, etc. Later in such cases the skin exhibits cicatrices. The skin may be discolored from the action of chemicals and dyestuffs or exposure to the sun and weather. Foreign material, powders, flour, etc., in many cases is deposited under the nails or in fissures or folds of the skin. Foreign particles, as of iron or iron oxide in grindstone workers, may become permanently embedded in the skin, producing a tattooage effect similar to the particles of gunpowder often found deposited in the cutis. Impregnation of the skin with substances like resins or sulphur may produce a corresponding distinct odor. Increase or decrease of the delicacy of the sense of touch may be produced by practice or by thinning or thickening of the epidermis. The temperature of the hand may be affected by alterations in the development of the superficial vessels, being lowered in those who work with their hands in cold water, or habitually elevated and increased in those who work in hot places (as bakers).

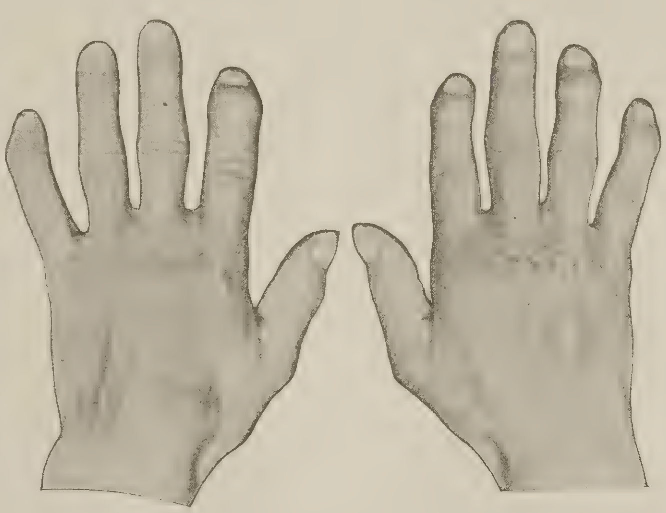
FIG. 2489.—Hands of a Baseball Player, Showing Characteristic Alterations. (Original.)

The nails are subject to special changes, as discoloration by chemicals or dyes, wearing off of the edges, or hypertrophy at particular points. The hairs may be discolored, or destroyed in places by pressure or chemicals.

The subcutaneous tissues may be thinned or thickened by the same factors that produce like results on the cuticle and cutis. The hands of those engaged in hard manual labor often exhibit a marked general palmar induration, the skin and underlying tissues being generally thickened, hard, rigid, and inelastic, and somewhat contracted so that the fingers are held slightly flexed and their full extensibility is somewhat impaired. From the action of irritants subcutaneous œdematous accumulations may be developed. Enlarged bursæ may appear at points exposed to pressure, as on the back of the right wrist in sawyers (Vernois).

The veins of the hand may become dilated from habitual exposure to heat. The muscles may to a certain extent become hypertrophied, atrophied, or shortened, according to their use or disuse. Special muscular activity and mobility and manual dexterity are developed in most occupations, as in pianists and many others. Habitual holding of the hand in certain positions, as with drivers, sometimes results in more or less rigid fixation of the hand or fingers in a flexed or other position—the *occupation* or *habit contracture*. Overuse of groups of muscles sometimes causes them to atrophy—*occupation muscular atrophy*. The nerves do not undergo perceptible anatomical alterations, but various occupations may produce serious functional nervous disorders of the hand, forming the important clinical class known as "occupation neuroses," typified by writers' cramp.

The articulations may be variously affected by occupation. Sometimes the mobility of the joint is increased, sometimes it is diminished, or there may be complete ankylosis. The finger joints may be enlarged, from exposure to repeated injury, as in baseball players. Partial luxations may occur, and deflections of the phalanges may be produced (as a backward deviation or superextensibility of the distal phalanx of the thumb in jewelers). From being kept in habitual special positions, corresponding changes may take place in the articular structures, as pressure atrophies, lengthening or shortening of ligaments, etc. Even the bones may undergo changes, as a spatuliform flattening of the phalanges from pressure.

From this résumé it will be seen that a great variety of changes in the hand may be produced by the occupation, varying in their situation, extent, and character according to the particular causative factors that may be at work in each case. The alterations may be anatomical or physiological, structural or functional. Three or four clinically important groups of conditions may be specially distinguished and mentioned: *occupation deformities*, in which alterations of form are produced; *occupation dermatoses*, embracing in general changes produced in the skin; *occupation dermatitis* and other inflammatory processes consequent upon the occupation; and *occupation neuroses*, covering the morbid functional nervous conditions induced by occupation or habit.

As an example of occupation deformities may be mentioned the effects often produced in the hands of baseball players, which are very characteristic (Fig. 2489). The typical changes in these cases consist in an enlargement of one or more of the distal phalangeal joints, along with slight lateral or palmar deflection of the terminal phalanges, which have a shortened appearance. Sometimes the affected joints are partially or completely ankylosed, though not always so.

No general rules as to treatment can be laid down, as the lesions and factors are so various in different cases. Change of occupation is obviously a therapeutic measure of general applicability in these cases. Occupation dermatitis and occupation neuroses will be referred to subsequently.

AFFECTIONS OF THE NAILS.

These are usually treated in full in works on dermatology, and will be only briefly reviewed here. The lesions of these structures may be divided into inflammatory and necrotic conditions (paronychias), changes in the substance of the nails (nutritive or trophic changes), atrophy, absence, hypertrophy, changes in form, changes in color, and parasitic conditions.

Inflammatory and Necrotic Conditions—Paronychia.—The nail substance from its histological structure cannot itself be the seat of real inflammation. The tissues contiguous to the nail and from which it derives its growth and nutrition (the bed, matrix, and root of the nail), are, however, subject to special forms of inflammation, and to such conditions the terms onychia (or onychitis) and paronychia are variously given. The term onychia is also applied to certain purely nutritive and trophic lesions of the nails. Other affections of these tissues in their clinical features resemble inflammatory paronychias, though primarily rather necrotic in character. The chief varieties of paronychia are the traumatic, infectious, malignant, syphilitic, tuberculous, diabetic, toxic, and trophic forms, besides those forms in which the cutaneous tissues adjacent to the nails are affected with various skin diseases, especially eczema and psoriasis. Of these forms of paronychia, the common acute variety due to infection with pyogenic bacteria and the syphilitic and tuberculous varieties have been already considered.

Traumatic Onychia and Paronychia is that caused by injuries, especially contusions. In cases of great violence the nail may be loosened and immediately cast off. In less severe cases, effusion and transformation of blood may give the nail a black color; in the course of time the nail often becomes slowly and gradually loosened from its bed, in whole or in part, and may be entirely cast off. If infection occurs the case is materially aggravated. The tendency is toward repair and recovery, with ultimate reproduction of a perfect nail. The parts should be kept protected, dead nail should be removed, and infection guarded against.

Malignant Paronychia (or malignant onychia) is an indolent inflammatory, suppurating, necrotic, or ulcerative affection of the nail matrix and bed, originating in a slight traumatism, and confined usually to a single nail. It affects especially persons of lowered vitality and in unhealthy condition, especially those of scrofulous diathesis, diabetics, and those prone to infections; it is commonest in children. It begins with simple inflammation, later proceeding to suppuration and ulceration. The nail becomes thickened, opaque, discolored, loosened, and cast off. The course of the disease is slow and indolent, and may become chronic; or the ulcer may slowly heal, and an imperfect nail be formed. The inflammation frequently extends to the subcutaneous tissues or the bone. In scrofulous cases the process is probably sometimes really tuberculous. The treatment consists in local measures to stimulate healing, and in vigorous constitutional and tonic treatment.

Diabetic Paronychia is the form of diabetic gangrene in which the circumungual tissues are the seat of the necrotic process or tendency, shown by sluggish inflammation or ulceration. The treatment is that of the constitutional disease.

Toxic Paronychia, that produced by the action of toxic agents, is well exemplified by the characteristic local lesions—ulcers at the roots of the nails—produced by arsenic in the hands of those who work with this substance. The obvious treatment is discontinuance of the cause.

Trophic Paronychia is the necrotic and inflammatory process about the nails which results from morbid nervous action in various neuroses such as syringomyelia or Morvan's disease, "glossy skin," Raynaud's disease, leprosy. The process is primarily degenerative and necrotic, but the lowered vitality of the tissues predisposes to sluggish infection and inflammation. The destruction of tissue may be extensive, involving even the bone, and the course is apt to be prolonged. The treatment is local and that of the cause.

Nutritive Alterations of the Nails.—While the nail substance proper is scarcely liable to inflammation, it is subject to nutritive and trophic alterations, mostly of a degenerative character, which may be produced by a considerable variety of causes.

The term onychia is applied to some forms of these alterations. The changes of a degenerative, malnutritive, or trophic character which the nails may exhibit are very various, such as loss of lustre, changes in color (white spots, etc.), softening, brittleness, friability, fragility, thinning, thickening, longitudinal or transverse furrows and ridges, laminations, exfoliation, splitting, irregularity of surface (elevations and depressions), etc.

These trophic alterations may be grouped into three etiological classes: (*a*) those due to local conditions or causes, as paronychia, dermatoses, trauma; (*b*) those due to constitutional diseases, especially those with a lowering of the general nutrition or vitality, and (*c*) those due to morbid trophic influences of nervous origin.

The paronychias do not all cause impairment of the nutrition of the nail, but in some cases, as in malignant paronychia, ulcerative syphilitic paronychia, and trophic or necrotic paronychias, the nail substance is apt to suffer, or may be entirely cast off. Skin diseases affecting the nails or adjacent cutaneous tissues, especially eczema and psoriasis, may cause malnutritive changes in the nails. Similar effects may be produced by trauma, contact with strong chemicals, parasitic affections of the nails, etc.

Severe constitutional diseases in which there is a great drain on the vital powers and the general nutrition is lowered, such as acute fevers, syphilis, scurvy, diabetes, gout, cancer, and others, also senility, may produce trophic changes in the nails. The syphilitic onychias have been already described. After acute diseases the ungual changes appear in the period of convalescence. Transverse furrows or white bands, representing temporary arrest of growth, sometimes appear after typhoid fever and other diseases. In relapsing fever two or three such transverse markings sometimes occur, one following and corresponding to each febrile paroxysm. Longitudinal ridges—"reedy nail"—occur in gout, senility, and other conditions.

In the third class of cases nutritive changes in the nails are produced by morbid, trophic, nervous influences arising from various nervous disorders, as in association with neuritis—multiple neuritis, gouty neuritis, leprosy, "glossy skin"—or with central nervous diseases.

In the treatment of these conditions the nails should be kept trimmed and in good order, protected by a coating of wax, and guarded against injury. The local or general condition giving rise to the ungual lesions should receive the appropriate treatment.

Atrophy of the Nail can scarcely be distinguished from certain forms of nutritive alterations, and is similar in its etiology and pathology to the latter.

Absence of the Nails (*Anonychia*) may be congenital or acquired. Rarely the nails are entirely absent from birth, either without any other developmental anomaly or in association with developmental defects like hypophalangism. The nail may be totally and permanently abolished by traumatisms or diseases causing complete destruction of the nail-forming tissues.

Hypertrophy of the Nail (*Onychauxis*) may consist in an increase in thickness, or in a lateral expansion (ingrowing nail). Both conditions are much commoner in the toes than in the fingers. In many cases enlargement of the nail is a result of nutritive abnormality, the increased nail substance being discolored, friable, brittle, fragile, etc. Hypertrophy of the finger nails occurs in connection with congenital dactylomegaly, traumatism, occupation effects, lack of cleanness, syphilis (hypertrophic syphilitic onychia), fungous growths, chronic skin troubles in the vicinity like eczema and psoriasis, nutritive and neurotrophic influences. The treatment is that of the cause.

Changes in Form of the Nails may result from traumatisms, occupation effects, nutritive or circulatory disturbances, or local disease. An increased transverse curvature is said to be produced by syphilis, hemiplegia, and free perspiration. An increased longitudinal curvature occurs in Hippocratic fingers and hypertrophic pulmonary osteo-arthropathy. "Spoon nail" is a condition in which the nail is concave transversely, with everted edges; it has been observed in connection with wasting diseases. Changes in relative length and breadth of the nails may also occur, as in rickets, in which the nail is said to be relatively shortened.

Changes in Color of the Nails may arise from staining by extrinsic substances or from intrinsic pathological processes.

The commonest change of color is to white, in the form of white spots, white bands, or whiteness of the entire nail. *White spots* on the nail ("flores unguium") are very common in children, usually occurring without perceptible cause; they may also be produced by injuries, trophic alterations, and constitutional diseases. Their pathology is not well understood. They are attributed to the presence of air in the nail substance. *Transverse white bands* sometimes appear after febrile attacks, sometimes occur in persons in good health, sometimes are congenital. *Complete whitening* of the nail occurs rarely, as after severe fevers or in paralytics.

Black Discolorations of the nails are common, from extravasation and transformation of blood pigment after contusions. Small black spots rarely appear on the nails after severe illness.

Parasitic Affections of the Nails.—The nails may be invaded by various parasites, either fungous (onychomycosis) or animal. The commonest form of onychomycosis is that produced by the trichophyton fungus; this, however, is infrequent, and usually secondary to or associated with tinea trichophytina elsewhere. Rarely the nails are affected by favus. Nails invaded by fungous growth are thickened, soft, brittle, lustreless, grayish or yellowish-white, and in a defective nutritive condition. The appearance is similar to that of nails suffering malnutritive or trophic alterations, so that the diagnosis is with most certainty made by microscopical examination.

Scabies occasionally affects the nails.

The treatment of nails infected with parasites consists in removal of the nail by scraping or applications of caustic alkali, with parasiticide applications (creosote, acetic acid, mercury bichloride, sulphur, etc.).

Affections of the Skin.

The consideration of the dermatoses of the hand and fingers belongs to the province of dermatology and can be only very briefly touched upon here. The skin of the hand is in general subject to disease in a similar manner to the rest of the body; but special or peculiar features are exhibited in many of the dermatoses of this locality, caused by exposure of the hand to atmospheric and meteorological conditions, to acute or chronic irritant influences of mechanical or chemical nature, and other factors.

Some dermatoses affect the hands indifferently or similarly or along with other parts of the body, without any peculiar features or special susceptibility or insusceptibility, as pemphigus, dermatitis herpetiformis, lichen ruber, ichthyosis, impetigo herpetiformis, prurigo, herpes zoster, molluscum contagiosum, scleroderma, mycosis fungoides, cornu cutaneum, and many others. To some dermatoses the hand is not at all subject, as seborrhœa, tinea versicolor; or less subject than other localities, as corns, psoriasis. To some dermatoses the hand is especially prone, and more susceptible than are many other parts of the body, though without manifesting any specially distinctive features, as erythema multiforme, herpes iris, pellagra, frambœsia, impetigo, impetigo contagiosa, callosity, warts, glossy skin, pompholyx, tinea circinata, scabies, occupation dermatoses. Some skin affections may exhibit peculiar features about the hand, as some forms of eczema and syphilides. Some dermatoses are peculiar to the hand, or to the hand and foot, as keratosis palmaris, affections of the nails.

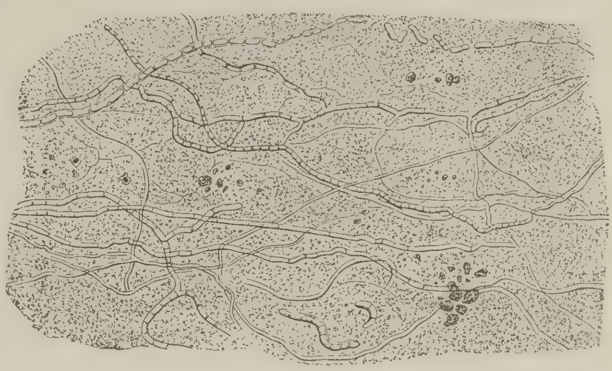

FIG. 2490.—Onychomycosis Trichophytina, Microscopical Appearance, Showing Fungus. (Kaposi.)

In many instances there is a marked difference in the liability of the palmar and dorsal surfaces of the hand to skin disease. Thus, the absence of hairs and sebaceous glands in the palm renders this area insusceptible to diseases of these structures, as acne. The dorsum of the hand is more prone to tuberculous dermatoses, erythema multiforme, keratosis senilis, tinea circinata; while the palm is more subject to most syphilides.

Eczema in its different varieties, acute and chronic, often occurs upon the hands, the liability of which to this dermatosis is increased by the exposure of these members to meteorological influences and to chemical irritants (especially alkalies). The chapping of hands is a form of eczema, induced by exposure to irritating influences. Onychias may result from eczema of the nails or their vicinity. On the palms eczema exhibits special features. Eczema about the hands is apt to be protracted and chronic, and very resistant to treatment. *Psoriasis* may occur both on the palms and backs of the hand, but is less common in this locality than in other situations. Occurring in or about the nails, it may cause an onychia. The backs of the hands are among the commonest seats of *erythema multiforme* and *herpes iris*. The hands are also favorite seats of *impetigo* and *impetigo contagiosa*. The hand may be affected with *dermatitis herpetiformis*, *pemphigus*, *herpes zoster*, *lichen ruber*, *ichthyosis*, and many other skin diseases in a manner similar to or along with other parts of the body. *Tinea circinata* is common on the back of the hands. *Favus* is much more rare in this situation; sometimes the nails become involved from scratching an infected scalp. The hand is the favorite seat of *scabies*. *Ainhum* sometimes occurs here and causes constriction and amputation of the fingers and even of the forearm. *Pompholyx* (or *dysidrosis*) is a rare vesicular affection, running on to maceration and exfoliation of the epidermis, that involves chiefly the palms and soles, though it may extend to or occur in other localities. *Callosities* are very common about the palm, resulting from habitual pressure or friction; manual labor also causes a general hardening of the palmar epidermis. *Corns* occasionally occur on the hand. *Keratosis palmaris* is a rare condition in which the epithelium of the palm becomes converted into a horny plate. *Glossy skin* is a trophic affection of the skin, due to nerve lesions or injuries generally, affecting especially the fingers; the skin undergoes malnutritive changes, or even actual necrosis, with onychia and pain. *Scleroderma* is a rare condition of sclerosis and contraction of the skin by which the hand as well as other parts of the body may be affected; in the hand it may produce great deformity and disability, the fingers being partly flexed, rigid, immovable, sometimes twisted, and in the later stages with atrophic changes. Tuberculous and syphilitic dermatoses, warts, and affections of the nails have been already considered.

Dermatitis of various kinds is common on the hands, due to their exposure to irritating conditions. Dermatitis traumatica results from traumatic irritation, dermatitis calorica from exposure to the rays of the sun or to other sources of heat and cold, burns, frost bites. In dermatitis medicamentosa lesions sometimes appear on the hands (as from the internal use of copaiba and chloral). The hands are very subject to dermatitis venenata, resulting from direct contact (either accidentally, temporarily, or habitually) with irritating or toxic substances, as in rhus dermatitis.

Allied to dermatitis traumatica, calorica, and venenata is a group of conditions which may be collectively designated *occupation dermatoses* or *occupation dermatitis*, to which the hand is very subject from repeated and habitual exposure to a variety of pathogenic influences incident to the occupation pursued. The changes in the epidermis, corium, and subcutaneous layer produced by occupation traumatism have been detailed above. In some occupations acute dermatitis may be set up from time to time. Thus, surgeons are sometimes subject to an acute inflammatory condition of the skin of the hands and forearms from hard scrubbing and prolonged exposure to liquids and to irritant chemicals like soft soap, mercuric bichloride, and oxalic acid.

For detailed information as to the clinical features and treatment of the various dermatoses of the hand reference should be made to works on dermatology.

Affections of the Bursæ.

The bursæ of the wrist, hand, and fingers may undergo development or enlargement, forming a variety of ganglion, either from pressure or irritation (as in some occupations), from rheumatic or gouty causes, or from causes not apparent. Rarely they may undergo inflammation —bursitis.

Affections of the Bones.

The affections of the bones of the hand are not sufficiently distinctive to require special consideration here. The involvement of the bones in developmental abnormalities, hypertrophic conditions, cartilaginous and bony tumors, fractures, infectious conditions, syphilis, and tuberculosis, has been already considered. Osteomyelitis, osteitis, periostitis, and other bone lesions do not present unusual features in the hand. In rickets the hand is little affected; the nails and terminal phalanges are said to be shortened in this condition. In osteomalacia the bones of the hand and fingers may become curved and bent; the distal phalanges especially are flattened, bent backward, blunt, and clubbed. The articular ends of the bones may participate in affections of the joints.

Affections of the Joints.

The articulations of the hand and fingers, while liable like other joints to the various arthropathic conditions, present some distinctive and peculiar pathologic features.

Injuries.—The ordinary injuries which these joints may suffer—wounds, blows, contusions—do not differ in their clinical characteristics or treatment from the like injuries of joints in general. Sprains of the wrist or finger joints require the usual treatment, immobilization, sedative or counterirritant applications, etc.

Dislocations of the joints under consideration may according to site be divided into radiocarpal, carpal, carpometacarpal, metacarpophalangeal, and phalangeal dislocations. From an etiological standpoint they may be divided into three classes: congenital dislocations, spontaneous (acquired) dislocations, and the ordinary traumatic dislocations.

Congenital Dislocations of any of the joints of this region may occur and have been observed, though very rarely.

A few cases of dislocations of the wrist existing at birth have been observed, forming a variety of club hand. The dislocation may be either forward or backward, and is generally associated with a shortening of the forearm. Both hands may be affected. The hands are usually well formed and quite useful.

A few cases are also recorded of congenital dislocation of the phalanges, at either the metacarpophalangeal or interphalangeal articulations, and in a palmar, dorsal, or lateral direction. Several fingers are usually involved simultaneously. The treatment consists in prolonged use of splints or corrective apparatus, with section of ligaments if necessary.

Spontaneous Dislocations or subluxations of the wrist or finger joints may occur in consequence of deforming or destructive joint lesions, as in arthritis deformans, or suppurative, tuberculous, or syphilitic arthritis.

There is a special class of cases in which a *spontaneous anterior subluxation of the wrist* gradually develops in adolescents engaged in hard manual labor. In this condition there is a partial forward dislocation of the carpus, with an undue prominence of the lower ends of the radius and ulna posteriorly, a diminished range of extension, an increased range of flexion, and a prominence of the flexor tendons. The ligaments are lax and the bones soft. Pain is usually present, at least until full growth is attained. This condition develops from about the age of fifteen to twenty-five years, in persons (especially females) engaged in hard manual work while the bones and joint structures are still soft, weak, and undeveloped. The superior strength and excessive action of the flexor muscles is supposed to be the determining cause of the anterior displacement. The deformity is difficult to overcome. The treatment consists in the use of corrective apparatus, stimulation of the strength and nutrition of the extensor muscles by massage, electricity, and exercise, the use of spring apparatus to reinforce and aid the action of the extensors, and suspension of excessive use of the flexors.

Traumatic Dislocations.—Dislocation of the wrist at the *radiocarpal* junction may occur backward or forward, or extremely rarely laterally (outward). This accident is far less common than Colles' fracture of the radius, which usually results from violence at this point. Reduction is effected by traction and direct manipulation.

Dislocation of the distal row of *carpal* bones from the proximal row has been noted in a very few instances. Dislocation of single carpal bones, forward or backward, may also occur. In some persons with weak and lax wrist joints single carpal bones may easily and repeatedly slip backward. Reduction is effected by pressure back into place, with use of a tight bandage to prevent recurrence.

Dislocation of metacarpal bones at the *carpometacarpal* junction rarely occurs. The metacarpal bone of the thumb is the one oftenest dislocated at this joint, the dislocation being forward, backward, or outward. The other metacarpal bones may also, very rarely, be dislocated either forward or backward. The bones may be dislocated singly, or more than one may be involved simultaneously. Reduction is usually easily effected by pressure of the bone into place, after which it should for a time be kept in position by splints or bandages to prevent recurrence.

Dislocations at the *metacarpophalangeal* articulations may be either forward or backward. The anterior luxations do not usually present special difficulties in reduction, which is accomplished by traction or by flexion, together with direct pressure.

The backward dislocation of the proximal phalanx of the thumb is a condition of some seriousness, from the difficulty sometimes encountered in effecting reduction. The phalanx may be superextended, or bent backward at an angle with the metacarpal bone; or in a still worse degree of luxation the base of the phalanx may overlap and lie behind the head of the metacarpal bone, the phalanx lying in the same direction as the metacarpus. The anterior ligament of the joint, which is firmly united with the phalanx but only loosely to the metacarpal bone, is torn loose from the latter bone, and if it becomes interposed between the ends of the two displaced bones it forms a serious obstacle to reduction. The lateral ligaments and the sesamoid bones in the tendons of the flexor brevis pollicis may also intervene between the two bones, while the slipping and retention of the base of the phalanx between the two tendons of insertion of the flexor brevis also interferes with reduction. Premature attempts to flex the dislocated phalanx only aggravate the trouble and should therefore be carefully avoided. In reduction, the metacarpal bone should be pressed toward the palm to relax the flexor brevis; the phalanx should be superextended well backward; the base of the phalanx should then be pushed by direct pressure into place, or until the anterior margin of its articular surface engages the posterior edge of the metacarpal joint surface; then by flexion of the phalanx the bone can be made to come into place. If this fails, rotation of the phalanx to free one side of the joint and then the other, combined with direct pressure or extension, may succeed. Sometimes all methods of manipulation fail, and a cutting operation may be necessary; in this case the anterior ligament may be put in proper position through a median palmar incision, or the tendon of the flexor brevis and the lateral ligament may be divided on one side, or pulled aside. In case of entire failure to effect reduction a moderate degree of movement and usefulness of the thumb will usually be ultimately obtained.

Dislocations of the other fingers at the metacarpophalangeal articulations are less common than of the thumb. They present similar features, sometimes similar difficulties in reduction of the backward luxations, and require the same treatment as in the case of the thumb.

Dislocations of phalanges at the *interphalangeal* articulations are common, and may take place in a palmar, dorsal, or lateral direction. Reduction is usually easily accomplished by traction and pressure.

A backward dislocation of the terminal phalanx occurs especially in baseball players (described by R. Abbe), in which the end of the middle phalanx is tightly caught between the flexor tendons and through an opening in the anterior ligament, rendering reduction difficult and often necessitating incision upon the joint in order to correct the displacement.

Ankylosis of the wrist or smaller joints of the hand and fingers is very common, resulting usually from traumatisms, blows, and wounds. Very slight injuries are often sufficient to cause ankylosis of these joints. Even prolonged immobilization may cause stiffening, even of the wrist; hence, in conditions like fractures, requiring prolonged fixation of the hand or fingers, it is advisable to practise passive movement, massage, etc., of the joints at sufficiently short intervals. . Operations about the finger joints, even if entirely aseptic, are exceedingly apt to be followed by ankylosis; in considering the advisability of operation in various cases this danger should be borne in mind, as the condition desired to be remedied may be preferable to possible or probable ankylosis consequent upon operation. After such operations the joint should be exercised frequently and for a long time to prevent ankylosis as far as possible.

Ankylosis may also be a sequela of inflammatory, infectious, or necrotic conditions. Congenital ankylosis of the small joints of the hand and fingers occurs rarely, sometimes being a hereditary abnormity of development. In a considerable proportion of cases of ossifying myositis a developmental ankylosis of the carpometacarpal, metacarpophalangeal, or interphalangeal articulation of the thumb is present.

There is little chance of completely restoring the mobility of an ankylosed finger joint, though arthrectomy or breaking up of the adhesions and bands may be attempted. If the joint is ankylosed at an inconvenient angle an improvement in the position can at least be obtained by operation.

Arthrogenous Deflections of the hand or fingers may arise from a variety of causes, as altered configuration of the joint structures (as in arthritis deformans), ankylosis in malposition, adhesions and contractions of the articular tissues, inflammatory or necrotic processes, developmental abnormities, dislocations, etc. The clinical features and treatment of these conditions vary with the cause. Hammer finger, due to shortness of the lateral ligaments, is an arthrogenous deflection that will be considered subsequently.

Enlargement of the joints of the hand is very common, and while (unless associated with partial or complete ankylosis) it usually causes little or no disability or impairment of function, it is unsightly. It arises from very diverse causes. Enlarged joints are very frequently produced by injuries (see Fig. 2489), and sometimes only slight injuries are sufficient to cause considerable deformity of this kind. The finger joints are often enlarged in persons engaged in manual labor. Deposits or hyperplastic processes about the joints, as in gout and arthritis deformans, are a common cause of enlarged joints. Another cause is found in neurotrophic influences, as in Charcot's arthropathy of locomotor ataxia and syringomyelia. Systemic conditions may also be etiological factors; thus, the proximal phalangeal joints are said to be enlarged in cases of dilated stomach. Enlarged joints of the hand should be treated according to their cause.

Secondary Alterations may develop in certain circumstances in the joints under consideration. When the joints (not being primarily affected) remain in fixed positions for a long time, as in the contractures of nervous diseases, Dupuytren's contraction, hammer finger, and the like, they after a time undergo compensatory, degenerative, or other secondary changes and become accommodated to their habitual position, so that if the primary cause of the malposition is done away with, the secondary alterations in the joint structures will still interfere with correction of the deformity. It is therefore important to avoid prolonged immobility or submobility of the hand or digits as much as is possible, so as to prevent secondary joint changes that may prove more or less irremediable.

Synovitis and Arthritis.—The inflammatory affections of the joints of the hand are chiefly of traumatic, infectious, tuberculous, syphilitic, gonorrhœal, or rheumatic nature. In addition to these are the rheumatoid arthroses, arthritis deformans, gout, and chronic rheumatism, characterized by abnormal trophic processes or deposition of abnormal material.

Traumatic Arthritis, resulting from injuries, without infection, may in the fingers be followed by ankylosis.

Infectious Arthritis in this member arises from infection by pyogenic bacteria, introduced through wounds or extension from neighboring infected areas.

Tuberculous Arthritis (which has already been referred to) as a primary disease involves especially the large joints of the body, among which the wrist occasionally suffers. The joints of the fingers may rarely be involved in tuberculous processes, but usually only secondarily by extension from tuberculous foci in the neighboring bones or skin.

Syphilitic involvement of the finger joints may occur in connection with syphilitic dactylitis, which has been considered above.

Gonorrhœal Arthritis occurs in the wrist and small joints of the hand in a considerable proportion (upward of ten per cent.) of all the cases of gonorrhœal rheumatism. It runs a course of very variable length, and of varying degrees of severity, from a mild synovitis to severe cases closely resembling infectious arthritis. The synovial membrane is especially affected, granulation tissue is often abundant, and ankylosis is very apt to result.

Neuropathic Arthritis.—In some cases acute inflammation of the finger joints appears to result from nervous influences. Marked trophic alterations of these joints may occur, of nervous origin, as in Charcot's tabetic arthropathy and in syringomyelia.

Rheumatic Arthritis (acute and subacute) affects by preference the large joints of the body, among them the wrist; but exceptionally the small finger joints are the seat of articular rheumatism.

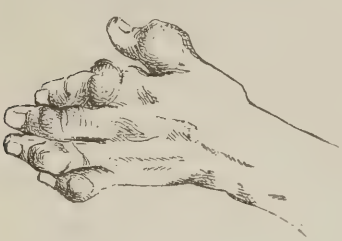

FIG. 2491.—Gouty Hand. (Meillet and Richer.)

Chronic Rheumatism includes a rather indefinite class of cases which in their clinical features merge into or are sometimes difficult to differentiate from arthritis deformans. It occurs independently, or as a sequel of acute rheumatism. It is manifested by thickening of the fibrous structures of the joint, enlargement of the joint, stiffness, ankylosis (fibrous), ulnar deflection of the fingers, chronic synovitis, pain, slight creakiness of the joints. The finger joints may suffer from this condition, though the large joints are its more usual seats.

The treatment of the various inflammatory, infectious, gouty, and rheumatoid affections of the joints of the hand is the same as that of these forms of arthritis or constitutional disease in general. Simple inflammations require rest, sedatives, counterirritants, etc.; suppurating joints should be drained; rheumatism demands the appropriate local and systemic treatment.

Gout.—Next to certain joints of the foot, the joints of the fingers are the most common seats of gouty lesions. These consist of deposits of urates, at first in the articular cartilages, then in the synovial and fibrous structures of the joint, then in the tissues surrounding the joint. These deposits, when in sufficient amount, constitute "tophi" or "chalk stones," and produce characteristic nodular enlargements about the affected finger joints. The mobility of the joints may be impaired. At times the tophi may ulcerate out, or may cause damage to the articulation itself. Urates may be also deposited in the cutaneous or subcutaneous tissues of the palm, or in the tendinous structures. The treatment is that of gout in general.

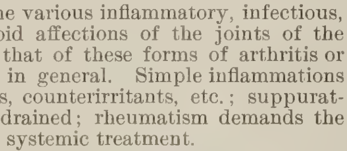

FIG. 2492.—Arthritis Deformans. (Meillet and Richer.)

Arthritis Deformans.—Under this designation is included a group of conditions which, while somewhat distinct in their clinical features, present common characteristics in the nature of the joint lesions. The finger joints are favorite seats for the different varieties of arthritis deformans, though other joints, especially the knees, are also subject to the disease. The characteristic pathological features of the lesions in these cases consist primarily in a proliferation of the cartilaginous structures of the joint. The central portions of these softened cartilages, exposed to pressure and friction, become eroded, leaving the bone bare; the exposed bone then becomes hardened or "eburnated." The marginal portions of the hyperplastic cartilages grow out into nodular masses about the margin of the joint; these outgrowths —"osteophytes"—become ossified. The ligamentous structures become thickened, subperiosteal bone formation is active, the muscles in the vicinity become atrophied. From the altered conformation of the ends of the bones deflections of the phalanges are brought about; the osteophytes limit the motion of the joint or may render it entirely immovable; the naked bony surfaces crepitate roughly.

The manifestations of rheumatoid arthropathy in the hand vary from the mild nodes of Heberden, or a still milder though characteristic ulnar deflection of the fingers, up to typical and extreme deforming and disabling joint lesions.

The typical and well-marked cases of arthritis deformans occur in both acute and chronic forms; while it usually develops in adults, especially in females, and most frequently during the third decade of life, an infrequent form of the disease occurs in children. The changes in the hand are often highly characteristic. The finger joints are enlarged and nodular; their mobility is decreased or they may be entirely immovable; they crepitate harshly; the phalanges are deflected laterally, backward, or forward. The wrist may also be involved. The deformity is unsightly, and the disability may be complete, the locked, distorted, and immovable fingers being incapable of any use. Both hands are affected; and several or all the joints are involved. The disease is progressive for a period, one joint becoming invaded after another, until a period of final arrest occurs. The fingers (all excepting the thumb) are usually deflected toward the ulnar side, at the metacarpophalangeal articulations, in a very characteristic manner; exceptionally radial deflection of the fingers is observed.

In severe cases a rather characteristic deformity may be manifested, consisting in a flexion of the proximal and terminal phalanges, and superextension of the middle phalanges (Fig. 2493).

Little can be accomplished in treatment of these conditions. The damage once done is irreparable, and the most that can be hoped for is arrest of the progress of the disease.

Heberden's Nodes (distinguished by William Heberden, 1782) are small nodular projections or osteophytes which occasionally develop on the fingers, particularly on the sides of the distal phalanges and distal joints. They are said to appear oftener in women, at about thirty to forty years of age. They are usually regarded as a mild manifestation of arthritis deformans, and while not curable are considered as of favorable prognostic significance inasmuch as when they occur the disease does not extend to other joints or produce serious consequences.

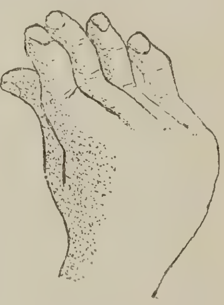

FIG. 2493.—Arthritis Deformans; Radial Deflection of Fingers and Superextension of Middle Phalanges. (Original.)

Ulnar Deflection of the Fingers at the metacarpophalangeal joints often occurs unassociated with any other evidence of rheumatoid articular disease, so that it may perhaps be regarded as a very mild form of arthritis deformans or rheumatoid disease. It is common in elderly persons, as if it were a senile change. It may also appear in earlier adult life as a consequence of acute or subacute articular rheumatism of the metacarpophalangeal joints. This condition, although but a slight deformity, presents a characteristic appearance; the little, ring, middle, and index fingers are slightly flexed, and bent laterally to the ulnar side at the metacarpophalangeal joints.

Changes in Extensibility of Metacarpophalangeal Joint of the Thumb at Different Ages.—In many cases the structures making up the metacarpophalangeal articulation of the thumb undergo progressive changes at different periods of life, such that while in childhood the proximal phalanx of the thumb is markedly lax and superextensible, in old age its extensibility may be diminished very much below the norm of the adult period. The condition of this joint is therefore to be considered in three periods—in childhood, in the adult, and in old age.

1. In young *childhood* in a large proportion of individuals the ligaments of the joint in question are very lax, so that the proximal phalanx can be superextended or bent backward at a marked angle, even to a right angle (see Fig. 2494). Usually the superextension can be accomplished by the free and unassisted action of the extensor muscles; occasionally the superextension can be brought about only by assistance or passive action. The position of superextension is a sort of subluxation of the joint, and the phalanx when extended goes back with a sudden slip. The condition is by the laity often called "double-jointedness." This laxity of the joint is very common in children up to the age of six or seven years, occurring to a greater or less degree in nearly a half of white children. After that age the superextensibility gradually diminishes, until about the age of puberty, when it usually has entirely disappeared. Occasionally, however, superextensibility of the thumb persists to maturity, especially in persons whose finger joints generally are unusually lax, and in those in whom this laxity is developed and maintained by such occupations as piano-playing.

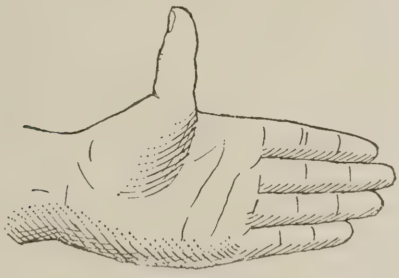

FIG. 2494.—Hand of a Boy Six Years Old, Showing Voluntary Superextension of Thumb. (Original.)

The superextensibility varies in extent, from a slight increase to an extreme degree of laxity. Usually both thumbs are superextensible, though sometimes one thumb, especially the left, may be affected alone. The left thumb appears to be rather more subject to this peculiarity than the right, as shown by its being often superextensible to a greater degree than the right when both thumbs are involved, and by its being most subject when only one thumb is affected. The two sexes are about equally subject to this condition.

In an examination, by the writer, of the hands of 161 white children from three to fourteen years of age the following data as to this condition were found:

Age (years).	THUMBS NOT AT ALL SUPEREXTENSIBLE.			ONE OR BOTH THUMBS MORE OR LESS SUPEREXTENSIBLE.				Total.
				Number.			Per cent.	
	Male.	Female.	Total.	Male.	Female.	Total.		
3–6	4	12	16	10	3	13	45	29
7–10	27	24	51	5	10	15	23	66
11–14	30	28	58	5	3	8	12	66
Total ...	61	64	125	20	16	36	22	161

Of the 36 cases in this series in which one or both thumbs were more or less superextensible, both thumbs were slightly superextensible in 6, and were markedly superextensible in 19; the left thumb alone was superextensible in 10; the right thumb alone was superextensible in 1—total, 36.

Among 73 colored children, 38 girls and 35 boys, aged from two to fifteen years, superextensibility of the proximal phalanx of the thumb was noted in only two instances (girls, aged ten), and that to a slight degree only. This would indicate that the peculiarity is less common in the negro race.

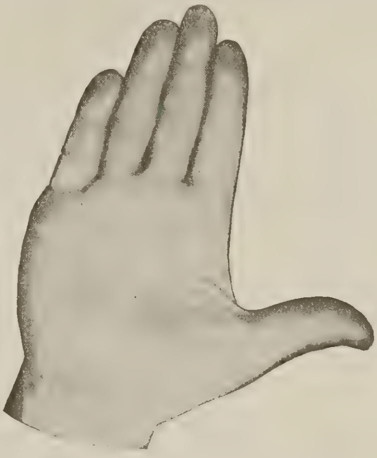

FIG. 2495.—Hand of a Man Aged Thirty-three, Showing Full Normal Adult Extension of Thumb. (Original.)

2. In the *adult* period the first phalanx of the thumb when fully extended normally lies in line with the metacarpal bone, or at an angle slightly short of this line (Fig. 2495).

3. In *old age* not infrequently the proximal phalanx of the thumb is very much decreased in extensibility, so that when fully extended it cannot be brought within a considerable angle (often not within forty-five degrees) of the line of the metacarpal bone extended) (Fig. 2496). With this, the distal phalanx is often considerably superextended and curved backward. The condition occurs alike in those who have or have not been subject to rheumatism, and in those who have or have not pursued laborious manual occupations.

The superextensibility of the thumb in childhood appears to be due to laxity of the ligamentous structures of the metacarpophalangeal joint. Its subextensibility in old age appears to result from shortening of the ligaments or alterations in the configuration of the hard parts of the joint, produced either by senile changes or perhaps by a mild and distinctive form of arthritis deformans.

Senile Joint Changes.—The finger joints in old age often exhibit alterations, which are partly due to mild rheumatoid lesions, partly to real senile changes. The finger joints often have a diminished range of mobility. They sometimes have an en-

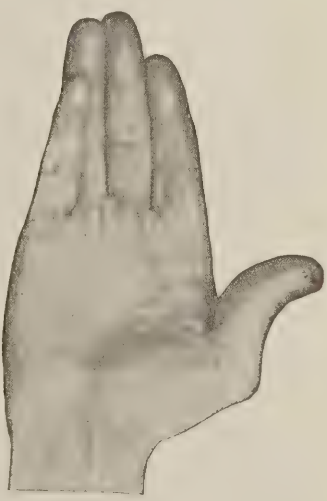

FIG. 2496.—Hand of a Man Aged Sixty-Nine, Showing Full Extension (Much Diminished) of Proximal Phalanx of Thumb. This subject had been a clerk by occupation, doing no manual labor, and had not had rheumatism. (Original.)

larged appearance, partly from real enlargement, partly from atrophy of the soft tissues of the phalanges. Ulnar deflection of the fingers is frequently seen, without other material evidences of rheumatoid arthropathy. As just considered, the metacarpophalangeal joint of the thumb often undergoes a characteristic decrease of extensibility.

Affections of the Tendons and Tendon Sheaths.

Small fibromatous *tumors* occasionally develop on tendons, especially on those of the flexor muscles of the fingers, palpable as subcutaneous nodules moving with the tendons and not causing material trouble unless they interfere with the action of the tendon or become painful from pressure. Some forms of trigger finger are produced by the impediment to motion caused by such tendinous nodules.

Tenosynovitis.—One of the favorite seats of various forms of inflammation of the tendon sheaths is about the wrist, hand, and forearm. Infectious and suppurative inflammation is common in connection with whitlows and palmar abscess; pain is intense, early and free incision is necessary, and the consequences may be serious. Gonorrhœal tenosynovitis sometimes occurs about the hand, and syphilitic involvement of these structures may occur.

Acute non-suppurative tenosynovitis may occur in the hand or forearm, from occupation irritation, contusions or other traumatisms, or spontaneously from undeterminable causes. The symptoms are pain, swelling, friction and crepitation, effusion of fluid.

The treatment consists chiefly of rest and immobilization and sedative or counterirritant applications.

Chronic Tenosynovitis in all or nearly all cases is of tuberculous nature. Most of the cases occur in the forearm and hand. It presents a number of forms—a simple serous effusion into the thecal sac, an effusion with rice-grain bodies, or an exuberant granulating form. It occurs more especially in women, in the delicate and unhealthy, and in those with a family or personal tuberculous taint; manual work, like wringing clothes, sometimes predisposes to it. The onset is gradual and the course very chronic. Pain is not severe.

In the forms with effusion there is an elongated swelling along the course of the tendon, with fluctuation. If the "rice-grain" or "melon-seed" bodies are present, they can be felt and can be rubbed on the tendon or sheath with rough friction. The inflammation may be confined to a limited portion of the tendon, or may extend the entire length of the sheath and to other sheaths.

In the fungous granulating forms the tendon and sheath are involved in an exuberant granulation process, which causes irregular distention along the sheaths, with a peculiar feeling, but no fluctuation.

The site of tuberculous tenosynovitis is especially on the dorsal or palmar aspect of the wrist, though it may extend along the anterior or posterior surfaces of the digits. At the wrist, the annular ligaments passing over the tendon sheaths may cause a constriction in the swelling at that point, forming an hour-glass appearance, sometimes called "compound ganglion."

The tuberculous process may extend to neighboring joints and other tissues. The condition may simulate lipoma, ganglion, chronic abscess, gumma, sarcoma; the diagnosis is made by the presence of fluctuation or rice bodies, the examination of aspirated fluid, and the tuberculous history. The treatment consists in rest, pressure, counterirritation, aspiration, injection of iodoform emulsion; incision with drainage; or incision, cleaning out the cavity, and immediate suture; or curettage, etc.

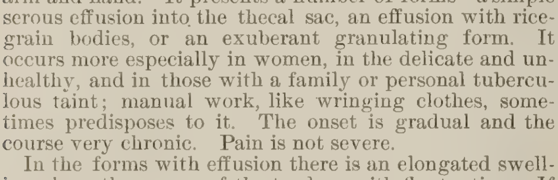

Fig. 2497.—Superextension Resulting from Non-Union of Flexor Tendons of Middle, Ring, and Little Fingers, Severed by an Incised Wound Twenty-Six Years Previously. (Original.)

Ganglion. — This occurs as a small subcutaneous rounded hard swelling, containing a viscid fluid; it is most commonly situated on the back of the wrist, but it also occurs in the palm, fingers, and elsewhere. Exceptionally it may be due to a hernial protrusion of articular synovial membranes or tendon sheaths, or to enlarged bursæ, but usually it is a cystic formation developing in connection with the walls of the tendon sheaths, but not communicating with their cavity. It is usually of slow development and sometimes disappears spontaneously. A soft swelling or ganglion on the back of the wrist is sometimes present in chronic lead poisoning. Its treatment consists in rupture by firm pressure or a blow, or evacuation by aspiration or subcutaneous incision. If it recurs after this treatment the cyst and its wall should be excised.

Injuries.—In incised wounds about the wrist, hand, and fingers, the tendons are frequently divided, partially or completely. When the section is complete corresponding impairment of function results, and if the tendon is not reunited permanent damage will ensue. In non-union of divided tendons, the action of the muscles involved is abolished, while unrestrained action of the opposing muscles causes a habitual or excessive deflection, in the opposite direction, of the bony parts supplied. Thus, section of the extensor tendons causes flexion and inextensibility of the phalanges, while division of the flexor tendons results in inflexibility, extension, or even superextension of the phalanges (Fig. 2497).

The consequences, as to the usefulness and appearance of the hand, of non-union of severed tendons are so serious that in all wounds of this region particular care should be taken to determine if any tendons are divided; and if so, the ends should be sutured together with catgut and the parts afterward kept at rest until union is obtained.

Subcutaneous rupture of the extensor tendons inserted into the distal phalanges sometimes occurs, giving rise to the condition known as mallet finger.

Adhesions of digital tendons to their sheaths or surrounding tissues are not uncommon from tenosynovitis, especially from whitlow or palmar abscess, or from cicatricial involvement after healing of wounds. Adherent tendons cause a corresponding loss of mobility of the parts supplied by them, or even a greater or less immobility in normal or abnormal positions—the so-called "tendinous ankylosis." In conditions in which adhesions of the tendons threaten to result, attempts should be made to prevent such a consequence. During immobilization of the hand in fractures early and frequent passive movement of the fingers should be practised to obviate tendinous adhesions. After thecal inflammations and wounds similar exercise of the fingers may prevent adhesions.

After firm adhesions are once established it is difficult or impossible to free the tendons, though a faulty position of a finger might be improved by operative measures.

Mallet or Drop Finger is an uncommon condition in which the essential lesion is a subcutaneous rupture of the extensor tendon inserted into the distal phalanx of a finger. It is caused by violence, often slight and insignificant, such as catching the finger tip in the clothing, or a slight push in the direction of flexion on the end of the finger. The tendon is torn at or near its insertion into the base of the terminal phalanx. The rupture may be complete; or it may be partial, a thinning or fraying and stretching of the tendon. In consequence of the rupture the power of extension (except passively) of the distal phalanx is lost, and from unopposed action of the flexor the phalanx drops limply forward and stands flexed at an angle (up to a right angle) with the finger.

Immediately after the injury there may be some inflammatory symptoms; but as these subside the phalanx is left helpless and inextensible in a flexed position.

The condition is said to be sometimes curable by keeping the phalanx well extended by splints for three or four weeks. If this fails operation is necessary. A longitudinal incision is made over the back of the joint, and the ruptured extensor tendon exposed; the severed ends of the tendon are then to be sewed together, shortening them if necessary; or the proximal end may be advanced and sutured into the periosteum or into the skin near the root of the nail. After the latter procedure the nail is sometimes temporarily lost.

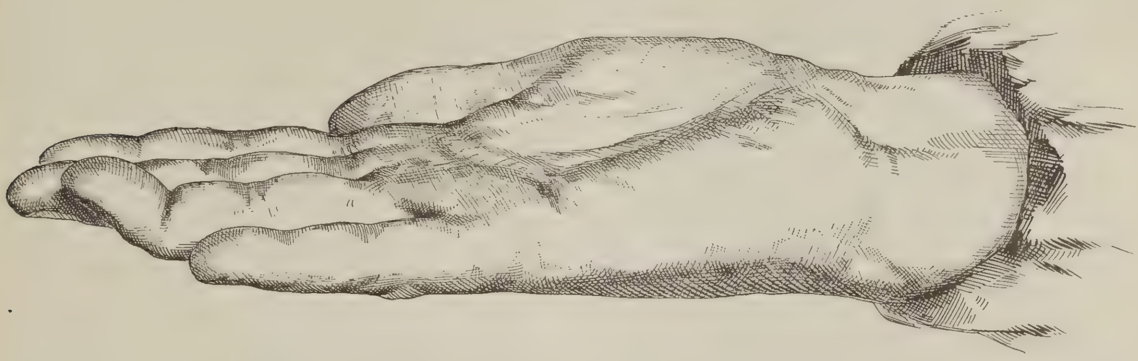

FIG. 2498.—Mallet Finger. (Abbe.)

AFFECTIONS OF CONNECTIVE-TISSUE STRUCTURES.

Aside from inflammatory and infectious processes in these tissues, the fascial and ligamentous structures of the hand are subject to certain characteristic affections, namely, Dupuytren's contraction of the palmar fascia, contraction of digital fascia, hammer finger, and general palmar induration.

DUPUYTREN'S CONTRACTION OF THE PALMAR FASCIA.

This not uncommon affection consists in a hypertrophy of definite tracts of the palmar fascia, with shortening of the hypertrophied band, resulting in flexions or contractions of the phalanges and changes in the configuration of the palm.

While not previously entirely unknown, the true nature of this condition was first demonstrated by G. Dupuytren, whose original deliverance on the subject was given in 1831. Numerous studies of the disease have since been made, an extensive literature has been produced, and several hundred cases have been recorded. Its morbid anatomy and mechanism have been settled by numerous operations and post-mortem dissections, but its etiology is still obscure.

The primary seat of this affection is in the palmar fascia or aponeurosis, a knowledge of the anatomy of which is essential to an adequate understanding of the pathology and mechanism of Dupuytren's contraction. The palmar fascia is a triangular or fan-shaped expansion of firm fibrous tissue radiating over the metacarpus, with the apex of the triangle situated at the depression between the thenar and hypothenar eminences (the "interthenar depression"), where the fascia is continuous with the annular ligament of the wrist and the tendon of the palmaris longus muscle. Opposite the metacarpophalangeal articulations there is a well-marked transverse fibrous band, the "superficial transverse ligament of the palm"; at this point many of the longitudinal fibres in the fan-shaped palmar fascia terminate, leaving a few fibres to pass to each of the digits, where they are attached to the skin and fibrous investments of the phalanges. At the web of the fingers there is another transverse fibrous band, the "fibres of Gerdy," or the "superficial transverse ligament of the fingers." The palmar fascia is situated immediately beneath the skin of the palm, from which it is separated only by thin masses of fatty and areolar tissue. The fascia is intimately connected with the skin by numerous fibrous bands—a point to be borne in mind in connection with the mechanism of Dupuytren's contraction. Microscopically, the fascia consists of coarse longitudinal and transverse bundles of dense white fibrous tissue, which in places are connected with the corium by smaller fibrous bands crossing through the fatty layer which separates the fascia from the cutis. Among the fibres elongated connective-tissue cells are numerous, and minute blood-vessels penetrate and accompany the fibrous fasciculi (see Fig. 2499).

Dupuytren's contraction consists essentially of a hypertrophy or hyperplasia of limited longitudinal portions or fasciculi of the fascia of the palm and fingers, together with, usually, contraction or shortening of the hypertrophied band in a longitudinal direction. This condition results in (1) flexions or contractions of the phalanges of the fingers caused by the traction of the shortened bands; and (2) induration and changes in the surface configuration of the palm, caused mostly by traction on the small fibres connecting the band with the overlying corium,

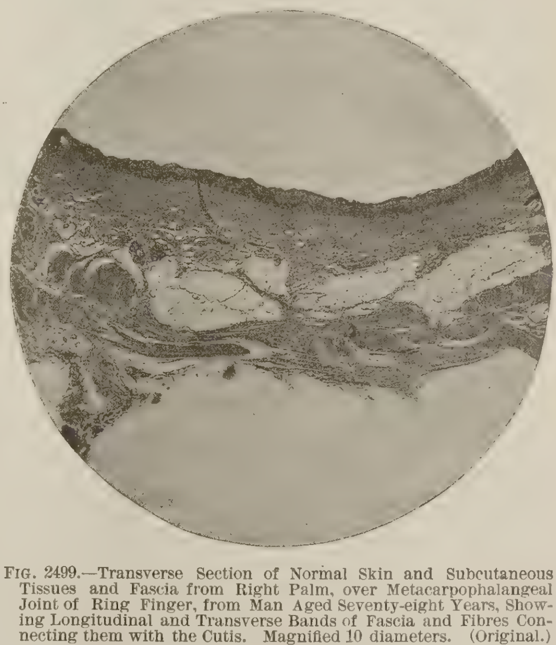

FIG. 2499.—Transverse Section of Normal Skin and Subcutaneous Tissues and Fascia from Right Palm, over Metacarpophalangeal Joint of Ring Finger, from Man Aged Seventy-eight Years, Showing Longitudinal and Transverse Bands of Fascia and Fibres Connecting them with the Cutis. Magnified 10 diameters. (Original.)

or by the thickened and elevated tissues beneath lifting up the skin. Whether the lesion is a hypertrophy or a neoplasm has been a point of discussion. The flexor tendons, which lie beneath the palmar fascia, are not in the least affected, though the bending of the fingers strongly suggests a muscular or tendinous pull. Prolonged malposition and immobilization of the joint in some cases produce changes in the affected articulations; involvement of the tendon sheaths has also been reported.

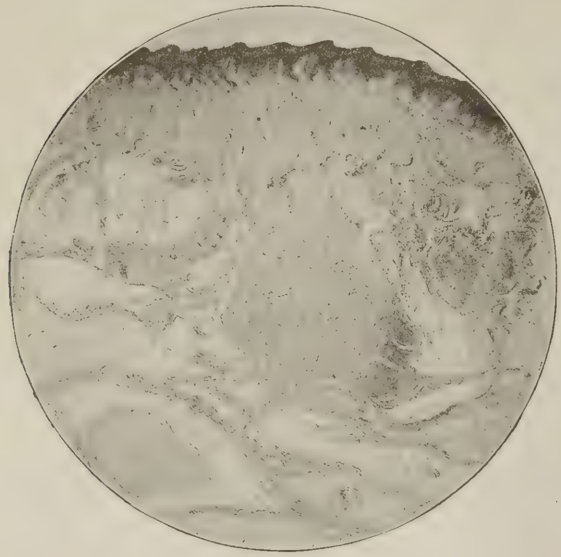

FIG. 2500.—Transverse Section of Skin and Band of Contracted Fascia Leading to Little Finger, Right Palm. Magnified 10 diameters. (Author's case.)

A few microscopical examinations of the lesion have been made, which afford some information as to its histology. The band causing the contraction, plainly visible to the naked eye, is a prominent rounded or oval longitudinal band of dense fibrous tissue, 2 to 5 mm. in diameter, belonging to the palmar fascia and situated in the subcutaneous tissue. The band may lie in contact with the cutis vera with nothing intervening, though the tissues of the corium and the band are usually distinctly marked off from each other without merging or being continuous together; or the band in places may be separated from the corium by an interval occupied by areolar and adipose tissue.

Microscopically (Fig. 2500) the contracted band is seen to consist of a dense aggregation of longitudinal fasciculi of white fibres, among which are elongated fusiform connective-tissue cells and small vascular channels in greater or less abundance. The tissue is essentially identical with that of the normal palmar fascia, being a hypertrophic or hyperplastic development of the latter. The skin in some instances is rather thickened and indurated, but aside from this all the other elements of the skin and adjacent structures are unaffected.

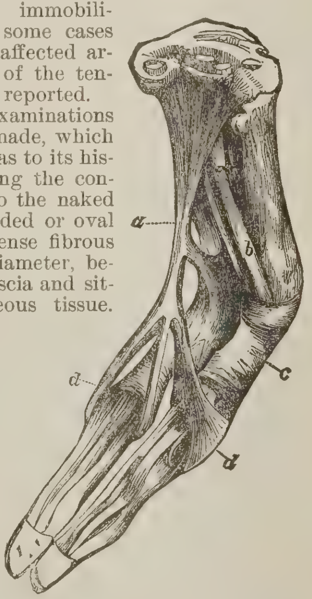

FIG. 2501.—Dissection of Dupuytren's Contraction of Middle and Ring Fingers, from a Specimen in St. Bartholomew's Hospital Museum. *a*, Contracted band of palmar fascia; *b*, flexor tendons; *c*, sheath of flexor tendons; *d*, insertion of contracted bands into base of middle phalanx. (Adams.)

In the early and developing period of Dupuytren's contraction the cellular and vascular elements are exceedingly abundant among the fibrous fasciculi of the contracted band. In this stage there may especially be observable a great accumulation of young connective-tissue cells, small, round, or spindle cells, in the adventitia of, or the tissues immediately surrounding, the small blood-vessels, which are also relatively numerous. Some young fasciculi are composed almost entirely of connective-tissue cells or fibroblasts, the fibrous elements being in process of formation. As the condition becomes of longer standing and in a stationary stage the vessels and connective-tissue cells decrease in relative abundance, and in old and long-established cases cells and vessels may be in very small number or altogether absent, leaving the fibrous band a dense sclerotic mass.

The condition seems to begin, then, as a rather active proliferation of connective-tissue cells about the small blood-vessels, which themselves become somewhat increased in number. The cells thus proliferating become fibroblasts and develop the fibrous fasciculi which constitute the contracted band. The process is therefore a fibrosis, limited to circumscribed longitudinal tracts of the palmar fascia, and is quite identical with the cirrhoses of the viscera or with the process often styled chronic interstitial inflammation. It is practically a hyperplasia or hypertrophy of longitudinal tracts of the palmar fascia, together with, usually, a longitudinal contraction of the affected tissue, the thickening being manifested in the transverse diameters.

Cases of Dupuytren's contraction may be in general divided into two clinical groups: 1. The ordinary typical cases in which there is contraction of one or more fingers together with the characteristic manifestations in the palm of the hand. The flexion of the fingers varies from marked deformity and disability to only slight limitation to the extensibility of the digit. This class, therefore, merges gradually into the next group without sharp dividing lines. 2. Cases in which the lesion is confined to the palm, there being hypertrophy of the palmar fascia and the characteristic thickening, induration, and altered conformation of the surface in the palm, but without contraction of the fingers. These cases are usually slight, yet they sometimes amount to considerable deformity.

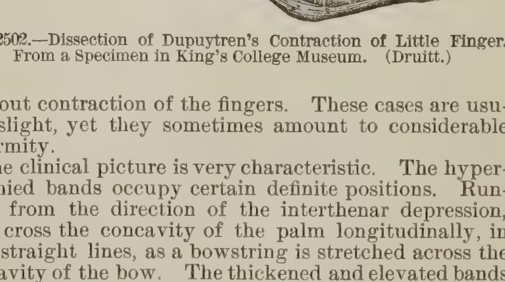

FIG. 2502.—Dissection of Dupuytren's Contraction of Little Finger, From a Specimen in King's College Museum. (Druitt.)

The clinical picture is very characteristic. The hypertrophied bands occupy certain definite positions. Running from the direction of the interthenar depression, they cross the concavity of the palm longitudinally, in taut straight lines, as a bowstring is stretched across the concavity of the bow. The thickened and elevated bands form prominent ridges across the palm, very apparent to sight and feeling. The bands pass in direct and definite lines to the fingers, having a definite locus and relation with the metacarpal bones, and do not take the direction of the interspaces between the digits. In the fingers the band usually follows the mid-palmar line; but occasionally, especially in the little finger, the band crosses the proximal phalanx obliquely, or lies toward one side. Ordinarily the bands in the palm do not branch, each finger having its band distinct from the others; but sometimes a band going to one finger divides near the metacarpophalangeal joint and sends a branch to an adjacent finger.

Besides the ridges formed by the elevated and thickened fascia bands, there are other characteristic alterations of the configuration of the surface of the palm (see Fig. 2503). Minute punctate depressions of the skin, pointing inward and often wristward, are common; they are caused by traction on bands connected with the cutis. Nodules like callosities, formed by indurations of the skin and fascia, are of frequent occurrence. The metacarpophalangeal articulations (especially of the ring finger) are favorite localities for these indurations and inversions of the skin, though they may occur anywhere over the proximal phalanges. The transverse line in the palm over the metacarpophalangeal articulations is often much deepened by the flexion of the fingers. The traction sometimes produces tension or stretching of the skin.

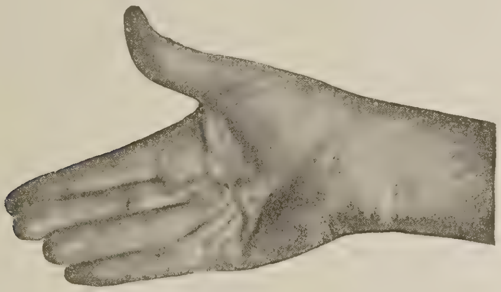

FIG. 2503.—Dupuytren's Contraction of Palmar Fascia, Showing Marked Changes in the Palm, with Slight Contraction of Ring and Middle Fingers. (Notice punctate depression of skin at distal end of proximal phalanx of middle finger.) (Original.)

The mode of distal termination of the bands varies somewhat. Many small fibres terminate in and are connected with the cutis, causing the characteristic depressions of the skin. In many of the cases in which the lesion is confined to the palm the bands terminate near the metacarpophalangeal joints, expending their force on the skin and subcutaneous tissues at those points instead of drawing on the fingers. Occasionally a thick and well-marked band proceeds some distance up a finger, yet (not being shortened) without producing any flexion of the phalanges. Many bands terminate by a general blending with the skin or subcutaneous fibrous investments of the finger, usually around the proximal phalanx; many others have a more or less distinct insertion, especially at the proximal end of the middle phalanx.

The contraction of the fingers is caused by the traction exerted by the shortened palmar bands, and consists in a limitation of the extensibility of the finger; within the limits allowed by the contracting band flexion and extension are unimpeded, but beyond them further extension is impossible. The degree of contraction varies from complete flexion of the finger into and against the palm to only slight limitation of the full extensibility of the finger. The contracting force may be exerted on any of the three phalanges, though almost always on the proximal or middle and only very infrequently on the distal phalanx. When the traction is exerted on the proximal phalanx, mostly by a general pull on the skin and fibrous investments, the finger is flexed as a whole on the metacarpophalangeal joint, the extensibility of the middle and terminal phalanges being unaffected. When the traction is on the middle phalanx, this is flexed on the proximal phalanx; and if, as commonly occurs, the band is sufficiently shortened, the proximal phalanx is also flexed on the metacarpus, although the band may not be connected with this phalanx. The distal phalanges are flexed and connected with the contracted band in only a very small proportion of the cases. Fingers adjacent to one strongly contracted are frequently slightly bent from traction of the fibres of Gerdy or the web of the fingers.

Either hand may be affected alone, or both hands may be involved together. In 184 cases collected by W. W. Keen, the right hand was involved alone in 58, the left hand alone in 23, both hands in 103. In 49 cases examined by the writer the right hand was affected in 12, the left hand in 15, both hands in 22.

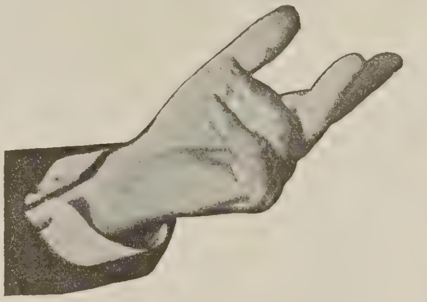

FIG. 2504.—Dupuytren's Contraction of Ring and Little Fingers. (Clarke.)

Any of the digits may be involved, but the thumb and index finger are rarely affected. The ring finger is much oftenest contracted, and the little finger in a large proportion of the cases; the middle finger is frequently involved, but not so often as the ring and little fingers. In 263 cases (214 collected by Keen, 49 observed by the writer) 572 fingers were affected in all, as follows: 12 thumbs, 24 forefingers, 93 middle fingers, 249 ring fingers, 194 little fingers.

One finger may be affected alone, or two or more fingers on the same hand may be contracted together. The commonest conditions are for the ring finger to be contracted alone, little finger alone, ring and little fingers, middle and ring fingers, in about the order stated. When two or more fingers on a hand are contracted, they are usually adjacent, though not always.

When both hands are affected, the contraction always or almost always begins in one hand before the other. Usually the two hands are affected to unequal degrees. Sometimes there is very little difference in the extent of the contraction in the two hands; in numerous other cases the hands are very unequally affected, one hand showing marked finger contractions while the other may exhibit only slight stigmata of the disease in the palm. The hand first affected is usually the one worse affected. The lesions are not exactly symmetrical in most cases, but have different locations in the two hands; thus, the ring finger of one hand and the ring and little fingers of the other may be the ones involved, or the ring finger of one and the middle finger of the other, and so on for a large number of possible combinations; still, in some cases the same digits are affected on the two hands. In the great majority of the bilateral cases, therefore, the two hands differ in the time of onset of the disease, the degree of the contractions, and the location of the lesions.

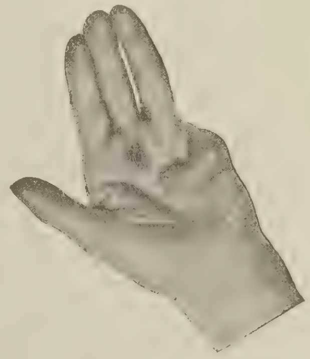

FIG. 2505. — Extreme Dupuytren's Contraction of Little Finger. (Original.)

As to the frequency of Dupuytren's contraction, William Anderson states that of 2,600 adults of the poorer classes in certain English infirmaries, about five-sixths of whom were over middle age, 33, or 1.27 per cent., were affected in various degrees, while of 800 children under sixteen none was affected. Noble Smith among 700 elderly inmates of English workhouses found 70 cases (10 per cent.) of Dupuytren's contraction, in 15 of which the disease was confined to the palm; in 444 women examined by him 11 had well-marked finger contractions and 15 others had simply palmar induration; this would leave 256 men among whom occurred 44 cases (17 per cent.). In an examination made by the writer of this article of the hands of 1,000 men, all ex-soldiers, ranging in age from twenty-one to eighty-five years and averaging about fifty-three years, 39 cases (3.9 per cent.) of Dupuytren's contraction were found; in 13 of these cases the palm only was affected, without contraction of fingers, leaving 26 (or 2.6 per cent. of the whole) having material contraction of the fingers.

Both sexes are liable to the disease, but women are affected much less frequently than men.

The influence of heredity in the causation of the disease is marked, a hereditary or family history of the occurrence of the affection being obtainable in about a fourth or a fifth of the cases.

The disease develops not only in the hands of persons engaged in manual occupations, but also, in large numbers, in persons not engaged in manual labor, and even in persons completely idle.

Dupuytren's disease is a disease of the adult and senile period of life, the favorite age of onset being from fifty to seventy years. Cases do, however, develop during the first half of life, and it is said that even congenital cases occur. It is possible that many of the cases alleged to have appeared at an early age were in reality cases of hammer finger, a condition that has only recently been distinctly differentiated. In 90 cases collected by Keen the ages of onset were as follows: after forty years, 47 cases; from thirty to forty years, 18 cases; under thirty years, 25 cases, of which 4 or 5 were congenital. In 45 cases examined by the writer the ages of onset were as follows: under twenty years, 1 case; from thirty to forty years, 7 cases; from forty to fifty years, 6 cases; from fifty to sixty years, 16 cases; from sixty to seventy years, 12 cases; over seventy years, 3 cases. The latter figures indicate that the disease is rare under thirty years of age.

The onset and development of Dupuytren's contraction are usually gradual and insidious, being manifested by slow development of the induration and deformity without subjective symptoms. Rarely pain or other symptoms in the affected area may precede the appearance of the contraction. As a rule the disease has a definite period of development, and then remains stationary. The period of development of the contraction usually ranges from a few months to three or four years; occasionally the lesions may develop within a few weeks, while in other cases the process of contraction may continue for many years. Sometimes there is a certain amount of intermittency in the development of the contractions; the lesions develop to a certain degree, remain unchanged for months or years, and then have another period of increase. This is especially manifest in the bilateral cases, in which after full development of the lesions in one hand a quiescent period of perhaps years may elapse, when the other hand becomes affected.

Subjective symptoms, pain, tenderness, or abnormal sensations, connected with and located in the seat of the contraction occur in only a small proportion of the cases. In some instances the pain is worse or exists only during the early period, though it may occur at intervals after the full establishment of the contraction as well as during the period of development. The abnormal sensations are often an occasional stinging or pricking feeling in the affected region; also a sensation of numbness or itching, dull aching pains, or sharp shooting pains. Tenderness is occasionally present, especially from exposure of the projecting surfaces to irritation; a feeling of tension in the palm is sometimes noted.

The milder degrees of the disease do not cause trouble or discomfort, and only exceptionally are any of the cases attended with pain. The severer forms of the contraction cause material deformity and disability, the exposed areas in the palm being unduly subjected to pressure and irritation in the use of the hand, the bent finger being awkward and in the way, and the function of the finger being impaired by its lack of extensibility. Occupations requiring the use of the hand may be interfered with. The condition once established is permanent unless obviated by surgical measures.

The diagnosis of the condition from other affections of the hand is usually easy. The bent finger, the ridge in the palm corresponding to the contracted band, the rounded, callus-like indurations, the small wristward inversions of the skin, and the definite location of the lesions are characteristic features which even in mild cases distinguish the affection. Even faint stigmata of the disease are quite distinguishable. Contractions from tendon lesions do not exhibit the characteristic surface changes of fascia contraction. In cicatricial contractions there is the history of injury, the scar tissue, the absence of the typical features of Dupuytren's disease. Arthrogenous deformities are recognizable by the history, the anatomical features present, or the constitutional condition; arthroses may coexist with Dupuytren's disease, however, introducing an element of doubt as to the precise share either may have in the production of the deformity present. In contractions limited to the digital fascia, surface and palmar changes are absent. Hammer finger exhibits no palmar or cutaneous changes, and is sufficiently characteristic to be readily distinguishable; it is probable that some of the cases diagnosticated and recorded as Dupuytren's disease, especially among the alleged congenital cases and those stated to have developed in early life, were in reality instances of hammer finger.

The etiology of Dupuytren's contraction has not been satisfactorily determined, and very diverse theories as to its causation have been advanced.

One prominent theory, held among others by Dupuytren, is that the disease is induced by slight local traumatisms or by continuous use and irritation of the palm incident to manual labor. In probably a majority of cases there is a complete absence of any history of local causes to which the lesions are attributed. In a smaller proportion of the cases the disease is attributed by the subject of it to local traumatisms like wounds, abscesses, blisters, irritation, or occupation incidents; but only rarely is the history sufficiently distinct or the connection sufficiently authentic to warrant any such conclusions. The assumption that in all cases a forgotten traumatism must have occurred is not logically justifiable. Persons not engaged in manual occupations are as subject to Dupuytren's disease, indeed rather more so, than are persons who habitually do manual work, and the disease may develop in the hands of persons entirely idle. The nature of the occupation is not altogether a safe criterion, since the soft hand of the nonworker is more easily irritated by occasional unusual use or strain.

On the whole, the statistics of numbers of cases are adverse to the theory of the local traumatic causation of the disease. There are other considerations opposed to the theory of traumatic origin and in favor of the contrary view of the idiopathic origin of the affection. The left hand is not materially less susceptible than the more-used right, and the ulnar half of the hand is much more frequently involved than the radial half, which bears the brunt of use to an equal if not greater degree. The favorite age of onset is after middle life, years after the period of active labor begins. The marked influence of heredity, the limitation of the disease to definite longitudinal tracts, the secondary development of contractions in the other hand after one has become affected, are unexplainable on the local traumatic theory. There is little doubt that Dupuytren's contraction is essentially of idiopathic origin, and that local traumatisms have no more than, perhaps, some occasional influence in lighting up the disease.

A germ theory of the disease has been presented by William Anderson, who considers the condition to be a chronic inflammatory process probably set up by a microorganism. This theory has not been substantiated, and does not seem probable in view of the protracted and benign course of the disease and the absence of inflammatory phenomena; and especially as it throws no light on the bilateral occurrence of the lesions and the influence of heredity.

The theory that the disease is a manifestation of some constitutional condition, especially of gout or rheumatism, is at present the one most generally held. These diseases occur in many cases of Dupuytren's contraction; but it has not been shown that rheumatism or gout affects persons with the palmar disease in a greater proportion of cases than they would a like number of individuals of the same class and age free from palmar contraction. In many cases there is absolutely no history of gout or rheumatism, family or personal. By many authorities gout is strenuously asserted to be the specific cause of Dupuytren's contraction, but this can hardly be successfully maintained. The disease occurs in America, where typical gout is uncommon, and often among social classes not subject to gout. In only a very few of the cases observed by the writer was there any history that could be construed as gouty. In many of the cases cited in support of the gouty theory the evidences of gout are vague, remote, and doubtful, and there is little to indicate that the coexistence of the two conditions is more than coincidental. The argument that when no other gouty manifestation is present the contraction is itself the symptom which shows the existence of gout is an instance of circular reasoning. The disease does not appear to be a manifestation of, or to be essentially and specifically caused by, rheumatic or rheumatoid disease, gout, diabetes, syphilis, or any other such constitutional condition.

The possibility of the nervous origin of the disease is worthy of consideration. The marked predilection of the disease for the ulnar side of the hand shows to some degree a relation with the distribution of the ulnar nerve. The pricking or tingling sensation specified in most of the few cases complaining of pain is quite suggestive of the paræsthesia of nervous lesions. The involvement of both hands, one being affected subsequently to and to a less degree than the other, may point to the operation of sympathetic (nervous) action in reproducing the disease on the side opposite to that first affected. Sometimes very suggestive cases occur in which Dupuytren's contraction is associated with nervous disease producing trophic lesions, as syringomyelia, anterior poliomyelitis. In a case reported by Lange, a woman who had a contraction of both ring fingers had an attack of left hemiplegia, almost immediately after which the contraction in the left hand disappeared, the right palm remaining unchanged; this was a sort of reversed trophic action. In the majority of cases of Dupuytren's contraction there is no history of concomitant nervous disorder; and it would perhaps be difficult to show that in the comparatively few cases accompanied by nervous disease the coexistence is not merely coincidental. It is of course possible that obscure trophic influences might occur sufficient to cause this disease, but without other manifestations. While a neuropathic or trophic theory of the pathology of Dupuytren's disease is supported by some considerations, and is not improbable, it cannot be regarded as having sufficient basis for definite acceptance.

According to Robert Abbe's detailed neuropathic theory of this disease, the original cause is a slight traumatism of the palm, often forgotten; this peripheral irritation produces a central spinal impression which then sends a reflex influence back to the part originally hurt and incites a contraction of the fascia. This contraction then sets up a second series of reflex symptoms, and by sympathetic action causes a reproduction of the trouble in the opposite hand. Abbe lays stress on the irritation of the original traumatism or the tense contractions being an exciting cause of neuralgias, local and distant, joint inflammations, and other symptoms simulating rheumatism and gout, and various general symptoms and neuroses, and cites cases in which these disorders were relieved by operation on the contracted fascia. The cases on which this theory was based must have been exceptional. Ordinary cases, in which the lesion is the seat of little or no irritation and is perfectly benign and innocuous, do not bear out this theory.

Dupuytren's contraction is one of the scleroses, a hypertrophy or hyperplasia of connective-tissue elements, and is hence to a certain extent allied to the visceral cirrhoses, as of the liver, kidney, and lungs, arteriosclerosis, and the spinal scleroses. Cirrhoses of the liver and kidney are largely due to prolonged irritation of toxic substances circulating in the blood. Arteriosclerosis is due to similar causes, also to the irritating action of constant overdistention and to hereditary influences. These disorders show a marked association with toxæmic and other irritation, and this relationship suggests a similar causation for Dupuytren's disease. This recalls the theory of the connection of this disease with gout, or lithiasis, which is a form of toxæmia. Dupuytren's contraction, however, differs from the visceral scleroses in being sharply circumscribed while the latter are diffuse and general. Why the palm should be selected to suffer in this manner from irritants circulating in the blood, and especially why the hypertrophy should be limited to specific longitudinal fasciculi, does not appear. One would expect more general consequences from local or toxic irritation. Toxæmia does not appear to be a very probable cause of Dupuytren's contraction.

The only conclusion as to etiology that seems warranted is that Dupuytren's disease is of idiopathic origin, most apt to occur in the senile period, and showing marked hereditary influence. There is no one constitutional disease with which it is exclusively associated or of which alone it is a manifestation. It does not appear to be specifically caused by local irritation or traumatism, though this factor, as well as local or constitutional pathological conditions, may at times have some exciting or contributing influence. Perhaps it is a neuropathic or trophic condition.

Contractions of the plantar fascia have been reported analogous to those of the palm; induration or contraction of the penis, associated with Dupuytren's contraction, has also been observed. Keloid, fibromata, and cicatrices are allied in some respects to fascia contraction. The contraction of ligaments in talipes and arthropathies, and of cicatrices, also presents some analogies, especially with respect to longitudinal shortening.

Treatment.—The only hope of relief in Dupuytren's contraction rests in operative intervention, for which a variety of methods have been practised.

One of the most popular and efficient procedures is that of *subcutaneous division* of the contracted fascial band, especially advocated by William Adams. A small straight tenotome is introduced between the skin and the band, and the latter cautiously cut downward. This is done at as many points as is necessary to free the finger and enable it to be straightened; as many as twenty or twenty-five punctures may be required. The sections are made along the entire band, from its proximal to its digital end, as needed. The hand is then dressed, with an anterior splint, with the fingers extended. The results of this operation have been very satisfactory in the hands of numerous operators. Before the days of antiseptic surgery it was doubtless the most advisable procedure, but with the introduction of aseptic technique many of the former objections to open operations have become obsolete. Even at the present time the subcutaneous method is preferred by some surgeons; Adams states that it is less liable to be followed by recurrence than the open operation.

Transverse division of the cord at one or more places, sufficient to free the finger, has been practised by some operators, followed immediately or after some days by the use of splints. Dupuytren and others have made open transverse incisions through both skin and band. In Goyrand's method the fascial band was exposed by a longitudinal incision through the overlying skin, and the band itself then divided transversely.

Excision of the fascia band in many cases is a rational and preferable procedure, though at times when the fascia is closely connected with the skin it may be difficult to separate it well. A longitudinal incision is made through the skin over the cord, and the band then carefully dissected out, after which the wound is sutured.

In *Busch's operation* a long triangular skin flap is cut, having its base corresponding to the contracted phalanx and its apex in the palm at the proximal end of the band. This flap is dissected up, the fascia exposed, and the contracting fibres are divided until the finger can be completely extended. The flap retracts, and the resulting open wound, originally V-shaped, is sutured (without exerting too much tension on the skin) into a Y-form. Extension is applied after the wound is healed. This operation does not appear to have come into general use.

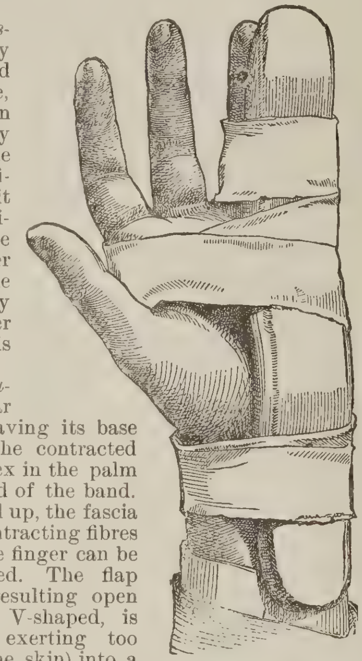

FIG. 2506. — Splint Employed After Operation for Dupuytren's Contraction. (Adams.)

A *plastic operation* is described by William Anderson as having been performed by him in one case. He made a transverse incision through the skin and fascia at the root of the finger, straightened the digit, and filled the gaping wound thus created by a flap of skin cut from the side of the finger and twisted around and sutured in place.

There is thus some choice possible as to the operation to be done. Wherever practicable,—that is, when the contracted band is well marked and easily separable from the skin,—it is probable that the band should be dissected out carefully through a longitudinal incision. But when the contracting tissues are poorly defined or the skin is extensively involved, multiple transverse sections of the band, open or subcutaneous, may be indicated.

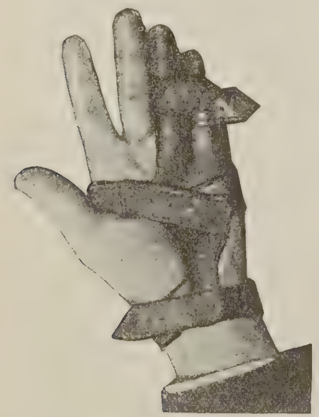

FIG. 2507.—Apparatus Employed After Operation for Dupuytren's Contraction. (Clarke.)

The post-operative treatment is very important, consisting of extension by splints or apparatus for a period sufficiently long to overcome the contraction or the tendency to recurrence. Operators have varied as to the time allowed to elapse after operation before mechanical extension is begun, some applying splints immediately, others not for several days afterward. It is probable that no greater degree of extension should be applied immediately after operation than can be employed without too great tension being exerted on the wound. After healing takes place, firm extension of the fingers by splints or apparatus (Figs. 2506, 2507) can be maintained for a few weeks, at first constantly, later intermittently, until a permanent result is obtained.

The final results of operative treatment of Dupuytren's contraction are generally satisfactory, though sometimes recurrence takes place.

CONTRACTION OF DIGITAL FASCIA.

The subcutaneous fascias of the fingers undergo contraction along with those of the palm in typical cases of Dupuytren's disease; and in some cases of hammer finger secondary digital fibrous contractions may perhaps be present. But aside from these, cases occasionally occur of fingers bent by hypertrophied and shortened bands of the digital fascia alone. There is little literature on the subject, but the writer has observed a very few cases of finger contractions caused by bands of digital fascia.

One case was that of an old man, from whom no reliable history was obtainable. The middle phalanx of his left little finger was flexed on the proximal phalanx at an angle of about 135°, and the terminal phalanx was slightly flexed on the middle one. A subcutaneous band could be plainly felt running along the ulnar side of the finger. A post-mortem dissection of this finger showed the presence of a firm thickened fibrous band attached to the fibrous investment surrounding the flexor-tendon sheaths, situated on the ulnar side of the palmar aspect of the digit; it extended the entire length of the finger and was the cause of the flexed condition of the latter.

A second case was that of a pensioner who at the age of fifty had a palmar abscess at the base of the right little finger, which was lanced on the radial side of the proximal phalanx. On healing, this finger became flexed at the proximal interphalangeal joint; the middle phalanx could not be extended beyond an angle of about 95°, motion within this limit being unimpeded. Along the radial side of the proximal phalanx, anteriorly, a subcutaneous band could be felt running to the middle phalanx. When examined the old scars were scarcely perceptible, and none was present over the contracted band.

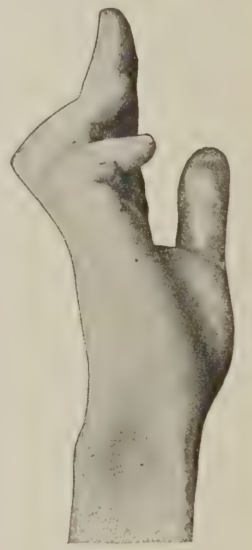

FIG. 2508.—Deformity Resulting from Contracted Subcutaneous Digital Fascia and Other Lesions. (Original.)

In a third case, a woman at the age of forty-three had an attack of cellulitis of the left hand and upper extremity, with much œdema or exudation, for which incisions were made at the base of the little finger and other points. After the attack subsided the middle phalanx of the little finger was bent to an angle of about 135°. The deflection subsequently increased. When examined at the age of eighty, the left little finger was flexed at both interphalangeal joints, the middle phalanx at a right angle, the distal on the middle phalanx to about 135°. The middle phalanx of the left ring finger also was flexed to an angle of about 130°. A tense subcutaneous band could be felt along the front of the proximal phalanx of each of the affected fingers, extending from the base of the middle phalanges toward the metacarpophalangeal articulation of the ring finger, where the two bands came together.

In a fourth case, a grocer aged about forty-five years had a severe and prolonged attack of cellulitis of both upper extremities and the right foot, following a slight infected wound in the left thumb. Incisions were made into the dorsal surfaces of the proximal phalanges, and about the wrists. After recovery a marked deformity of mixed flexion and superextension of the fingers of both hands existed. When examined, about twelve years afterward, the middle phalanges of the right ring and little fingers were flexed at a right angle; their proximal phalanges were superextended or bent backward about 45°, and their power of flexion toward the palm was very greatly impaired (Fig. 2508). The middle phalanx of the left little finger was flexed at an angle of about 100°, and its proximal phalanx was so superextended that it could not be brought within 45° of the straight line; the range of flexion of the proximal phalanges of the left ring, middle, and index fingers was also very much diminished. Along the front of the proximal phalanx of the right ring and little and left little fingers were tense elevated subcutaneous bands running from the bases of the flexed middle phalanges to the palm; these bands were probably fibrous, though they may possibly have been shortened flexor tendons. The superextension of the proximal phalanges was perhaps due to adhesions or shortening of the extensor tendons. Several hammer toes were present. The appearance of the hands was very similar to that of a variety of hammer finger described by Adams.

None of these cases showed the slightest signs of the changes in the skin and palm characteristic of Dupuytren's contraction, and the contracted bands seemed less superficial than in the latter affection. The typical appearances of cicatricial contraction were also absent.

These cases, and especially the one dissection, demonstrate that there sometimes occurs a condition of thickening and contraction of subcutaneous digital fibrous tissues resulting in a flexion and limitation of the extensibility of the phalanges. Further observations and dissections are needed to elucidate this condition and its position as a distinct affection. The little finger seems to be the digit most susceptible to this abnormity, at its proximal interphalangeal joint, precisely as in hammer finger. The affection is mostly unilateral, acquired, and may develop after local inflammatory conditions. It appears to be a disease process *sui generis*, and entirely distinct from cicatricial contraction and Dupuytren's contraction. It presents marked analogies to hammer finger, notably in its situation, and perhaps it may be regarded as a variety of hammer finger; still, to a certain extent at least, a distinction can be made between finger flexions due to fascia contractions and those due to shortened lateral articular ligaments as in typical hammer finger.

In diagnosis, finger deformities due to digital fascia contractions would have to be differentiated from those due to ankylosis, arthritic conditions, tendinous adhesions or shortening, cicatricial contractions, Dupuytren's disease, hammer finger (shortened ligaments), and such conditions. The cardinal feature indicative of fascia contraction is the presence of a subcutaneous fibrous band evident to the senses; it is conceivable, however (though perhaps not possible), that cases might occur in which a shortened and unusually elevated tendon might to the examining finger be undistinguishable from a fascial band. Moreover, cases might occur in which the subcutaneous fibrous tissues might be sufficiently shortened to cause deformity but yet not be palpable as distinct contracting bands; such cases might present difficulty in making a definite diagnosis.

The obvious treatment of this condition would be to divide or excise the contracting bands.

HAMMER FINGER.

There is a well-marked class of contractions or anterior deflections of the fingers, not very uncommon, manifested especially by a flexion of the little finger at the proximal interphalangeal joint, which is of distinctive nature. The affection has received very little attention in medical literature. It was described and figured in 1846 by R. W. Tamplin, who attributed it to contraction of the skin. After that it was occasionally mentioned by authors, but the fullest studies of the subject are those of William Adams and William Anderson, both originally published in 1891. The condition has mostly been called "congenital contraction of the finger," but Anderson applied the term "hammer finger" to it. The latter is the preferable designation, as it is concise, has sufficient metaphorical significance, expresses the analogy of the condition to hammer toe, and is non-committal as to the pathology of the affection or as to its being in all cases congenital.

Hammer finger is usually described as a congenital condition; but I have observed a few cases, exhibiting all the external and clinical features of hammer finger, which were distinctly acquired. Two varieties of the affection may therefore be considered: the developmental or congenital, and the acquired.

Developmental Hammer Finger.—This deformity typically consists in a flexion of the middle phalanx upon the proximal phalanx of the little finger at varying angles up to a right angle,—usually at an angle of about 135°. Slight limitations to full extensibility of the middle phalanx of the little finger are common, but unless the flexion amounts to about twenty degrees or more it is hardly worth while to regard it as abnormal. Within their respective limits flexion and extension of the affected phalanges are unimpeded; but beyond them further extension is impossible without the use of unusual force. In most cases the proximal phalanx is unaffected; but according to Adams it is sometimes bent backward or superextended (the middle phalanges being flexed), as is commonly the case with the corresponding phalanges in old cases of hammer toe (see Fig. 2508). The distal phalanges are also usually unaffected; but they are sometimes flexed instead of the middle phalanges, and in one case reported by Adams they were superextended, the middle phalanges being flexed. Some of the other fingers (especially the ring and middle fingers) are sometimes similarly affected in conjunction with the little finger, but to a less degree than the latter. In the congenital form the affection is usually bilateral, the hands being affected together though not always equally.

The skin over the anterior aspect of the finger is sometimes shortened or forms a longitudinal fold stretching across the concavity of the affected interphalangeal joint, increasing the antero-posterior diameter of the proximal phalanx. According to Adams, there are often present subcutaneous bands of contracted fascia, centrally or laterally located, sometimes with fibres inserted into the skin; but according to other authorities fascia contractions are absent. The author has not been able to detect contracted fascial bands in any of the developmental cases of hammer finger which he has observed; and in the pure uncomplicated developmental form of the affection it is probable that fascia contraction plays no essential part. In some cases there is some secondary shortening of the flexor tendons of the finger. Often the distal end of the first phalanx projects slightly at the angle of the articulation, but there is no subluxation of the joint. The lateral ligaments of the joint are shortened, and there may be other developmental or secondary changes in the joint. The contraction is entirely unassociated with injuries or arthritic or paralytic conditions. The contraction is not the seat of any pain or other subjective phenomena, but in its extreme forms may cause considerable deformity, unsightliness, and inconvenience.

The affection is markedly hereditary. Numerous cases have been observed of its transmission from parents to children and of its coexistence in brothers and sisters. It is frequently associated with hammer toe, either in the same individual or in the family. It is not a very uncommon condition, but is not often brought to the notice of the surgeon; it is much less common than hammer toe. It is said to affect females more frequently than males. In 800 school children Anderson found two cases among boys and five cases among girls. Among 1,000 adult men I found about five cases (one-half per cent.) of developmental hammer finger; possibly some cases were overlooked in this series before I learned to recognize this class of deflections. Among 177 white children under sixteen years of age the writer found two cases of slight hammer finger, one of the left hand in a girl, one of both hands in a boy; among 86 colored chidren no case was found.

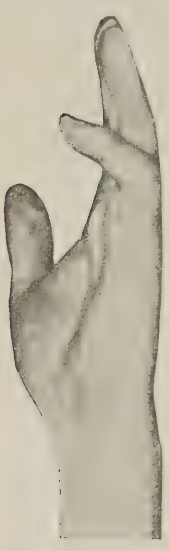

FIG. 2509.—Developmental Hammer Finger. (Original.)

While this form of hammer finger may or may not be manifest at birth, it usually makes its appearance very early, probably in the first two or three years of life. Adults affected will state that their fingers have been bent as far back as they can remember. Sometimes the contraction makes its appearance at a later age, even up to eighteen or twenty years, but always before maturity is reached. It is therefore a disease of the developmental period of life, and in that sense is congenital. The contraction slowly and continuously progresses for years, until the maximum is attained.

The essential pathological nature of hammer finger is only partially determined; opportunities for operation or dissection are not often presented. Several observers have regarded the flexed condition as due to shortening or contraction of the skin over the proximal phalanx; but this change in the skin, when present, is undoubtedly a secondary alteration and not the primary cause of the flexion. According to Adams, the deformity is due, partly at least, to shortened subcutaneous fascial bands. C. B. Lockwood, in a dissection of an amputated hammer finger, found a thickening and shortening of the fascia over the flexor aspect of the proximal interphalangeal joint, which caused the flexion; he did not state the condition of the articular ligaments. Other observers, however, have not found fascia contractions present, and they are certainly not an essential feature of developmental hammer finger, but only of secondary, occasional, and exceptional occurrence. The flexor muscles or tendons are not regarded as being the primary cause of the contraction, though they may be secondarily shortened. E. M. Little cut the tendons in one case, but without relaxing the finger; on the contrary, Anderson after cutting the other structures found that the flexors kept up the contraction.

The primary cause of hammer finger is apparently an abnormality, frequently hereditary, in the development of the component parts of the affected joint, resulting in a disproportion in the osseous, cartilaginous, and ligamentous articular tissues; the developmental abnormity results practically in a shortness of the lateral and anterior ligaments of the phalangeal joint, which interferes with full extension of the finger. The ligamentous shortening becomes manifest during the period of development. This is Anderson's view of the etiology of hammer finger, though he does not report any dissection. In a dissection made by the writer the contraction was found due, chiefly at least, to much-shortened lateral ligaments.

In long-established cases, in addition to ligamentous shortening, other changes are present; namely, alterations in the articular surfaces and shortening of the flexor tendons, fibrous tissues, and the skin over the proximal phalanx. These alterations are doubtless secondary changes, caused by the accommodation of these structures to the prolonged abnormal position. These secondary changes must be taken into account in operative procedures, as in old cases division of the lateral ligaments alone is apt not to be sufficient to correct the deformity entirely, as in a case operated on by Anderson and another by the writer.

Why the little finger, and the proximal interphalangeal joint of this finger, should be the especial seat of this abnormity, is a point that is not clear. The cause of superextension of the proximal phalanges as reported by Adams is also obscure. Hammer finger is allied in many respects to hammer toe. It is a distinctive condition, *sui generis*, easily recognizable, and entirely different from Dupuytren's contraction of the palmar fascia.

Acquired Hammer Finger.—I have observed a very few cases of flexion of the little finger at the proximal interphalangeal joint exhibiting almost precisely the same external appearances that developmental hammer finger presents, but which developed in adult life; that is, were acquired rather than congenital. An acquired form of the affection is recognized in the literature only by Tamplin.

In two cases bilateral hammer finger began to develop at the ages of eighteen and twenty years, and in both cases was attributed to slight irritation or blistering from manual work. These were probably developmental forms of the affection appearing unusually late; or the flexion may have begun earlier but been unrecognized. In one of these cases very slight stigmata of Dupuytren's contraction appeared in one palm nearly thirty years afterward, but no contracted bands were present.

In one case, a soldier at the age of thirty-seven suffered much exposure during a campaign and contracted rheumatism. At the same time both little fingers gradually or during a short period became contracted, and remained so unchanged for many years. The left little finger exhibited an extreme flexion into and against the palm caused by what appeared a Dupuytren's contraction of the palmar fascia (illustrated in Fig. 2505). The right little finger was bent at about a right angle at the proximal interphalangeal joint (Fig. 2510); there was no apparent thickening or contraction of the fascia either in the palm or in the finger, no change in the skin, no joint lesion, no sign of injury. Within the limits of the contraction the middle phalanx was freely movable, but beyond a right angle extension was impossible. The right little finger had the precise appearance of a hammer finger, and was distinctly not a Dupuytren's contraction, while the corresponding finger of the other hand was flexed by a subcutaneous palmar band.

In a second case, a laborer at the age of thirty to thirty-five years had a very slight Dupuytren's contraction of the fascia, in line with the ring and little fingers, develop in both palms, without bending the fingers; this continued without change. At the age of thirty-nine he sustained a slight wound in the palmar surface of the proximal phalanx of the left little finger, which healed in a few days. About a year later he noticed that this finger was bent; the contraction increased for a few years until at the age of forty-eight the middle phalanx was flexed at an angle of about 110°; no subcutaneous bands or contracted fascia could be distinguished.

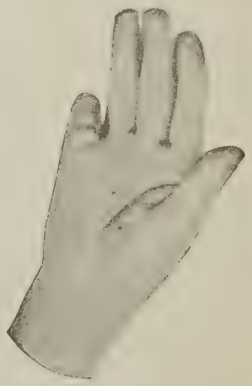

FIG. 2510.—Acquired Hammer Finger. (Original.)

In a third case, a soldier at the age of thirty-one had an abscess in the ulnar portion of the right palm, well toward the wrist, which was opened. Subsequently the middle phalanx of the right little finger became flexed at an angle of about 135°; there were no arthritic changes or subcutaneous bands, and no perceptible connection with the cicatrix in the palm.

These three cases show the possibility of the occurrence of an acquired deformity in appearance and seat precisely similar to developmental hammer finger. As compared with the latter the acquired affection is (so far as these cases show) unilateral, the degree of flexion rather greater, the skin less stretched. Within the limits of the contraction motion of the phalanx is unimpeded. In some of the cases the hammer condition is associated with Dupuytren's contraction of the palmar fascia, though in no way dependent on the latter. In some instances there is a possible relationship with antecedent traumatism. No contracted subcutaneous fibrous bands are perceptible, and no other lesions capable of causing the deformity can be detected.

In the absence of dissections the cause and anatomical changes of these acquired hammer fingers are obscure. They are not due to ankylosis, subluxations, or other joint changes, to cicatricial contractions, to skin changes, nor to perceptible fascia bands. Tendinous lesions might be possible causes. The deformity is probably due to shortening of some of the fibrous structures about the affected joint; whether the ligaments or the more superficial fibrous and fascial tissues, or both, remains to be determined. If the latter, the tissues must be generally shortened, and not thickened into bands perceptible to touch. The association with Dupuytren's disease may indicate the action of a common cause tending to produce shortening of fibrous structures in different situations. The peculiar susceptibility of one particular joint is an obscure point.

So far as the writer's observations show, acquired hammer finger bears a certain relationship to contractions of the digital fascia. The distinguishing point between them is the presence of evident subcutaneous bands in the latter. The significant fact that the proximal interphalangeal joint of the little finger is the articulation exclusively or chiefly affected in developmental hammer finger, acquired hammer finger, and digital fascia contractions constitutes a common point of relationship between these three affections, and indicates the existence of unknown specific etiological factors that render this particular joint especially liable to such changes.

The diagnosis of developmental and acquired hammer finger should ordinarily present no difficulty. The cases, especially congenital cases, are quite characteristic in their appearance, seat, and history. Flexions of the fingers due to injuries, arthritic changes, paralytic or spastic conditions, cicatricial contractions, section of extensor tendons, are usually easily distinguishable by their respective characteristics. Contractions of digital fascia are distinguished by the palpable presence of fibrous bands. Deformities produced by adhesions of flexor tendons or by fibrous ankylosis of the joints might be difficult to differentiate. To a certain degree the diagnosis, of the acquired form especially, is negative; that is, finger contractions of this type whose cause is obscure might for convenience be classed as hammer finger. Deformities due to Dupuytren's contraction are recognizable by an evident relation of the flexion of the finger with the palmar lesion; this relation is plainly demonstrable in Dupuytren's disease; although the two affections are entirely distinct, it is probable that cases of hammer finger have been diagnosticated Dupuytren's contraction, especially in alleged congenital cases of the latter affection.

Treatment of Hammer Finger.—The minor degrees of hammer finger do not cause sufficient trouble to require treatment. For the worse forms of the contraction treatment may be sought on account of the inconvenience or awkwardness of the bent finger or for the sake of appearance.

In young and mild cases, when the contraction is not too rigid and unyielding, passive motion and mechanical extension on a splint or special apparatus will often yield satisfactory results in the correction of existing deformity or the prevention of further deformity. To be effective and permanent such treatment must be kept up constantly and faithfully for a long time. The splint should be worn day and night for months, and then at night or at intervals, for a long time, until the persistent tendency to recontract is overcome. Special forms of apparatus have been devised for maintaining extension of the fingers.

In adults and cases of long standing, when the tissues are rigidly contracted and secondary alterations greatly augment the difficulties of treatment, the results of treatment are apt to be unsatisfactory. In such cases operative treatment is the only procedure offering any hope of relief. In considering the advisability of operative interference the liability of subsequent ankylosis from entering the joint, or of impaired mobility from interference with the tendons, should be borne in mind. Stiffening after operation on hammer toes does not affect the usefulness of the member. Stiffening of a finger in an extended position, however, is a material inconvenience and disadvantage, and no improvement over the hammer condition. The finger joints are very apt to become ankylosed by only slight injuries, and the risk and disadvantages of such a result or of unsightly enlargement of the joints should be remembered in considering operation. Recontraction is apt to occur.

Few cases of hammer finger have been operated on, so that data as to results or the best technique are scanty. The object aimed at is to divide all the structures causing the contraction. The shortened lateral ligaments should be cut, either through an open wound or subcutaneously. In inveterate cases a division of the ligaments alone may not suffice to free the finger, owing to secondary contraction of the skin, flexor tendons, and fibrous tissues. It will therefore be necessary to divide all the contracting structures—skin, fascia, tendons—until the finger can be straightened. Vogt claimed good results from plastic operations on the skin, as by cutting a V-shaped flap, straightening the finger, and suturing the resulting wound in a Y-shape; this would obviously afford relief only when the contraction is due to shortening and tension of the skin and superficial tissues. Contracted fibrous bands may be divided subcutaneously, as recommended by Adams. Shortened tendons may be and have been divided, or they might be lengthened by a plastic operation. Interference with the tendons, however, has been and is apt to be followed by non-union or adhesions, resulting in a very undesirable impairment of the motility of the finger. After operation extension of the digit by splints or apparatus should be maintained for a long time to overcome all remaining deformity and to prevent recurrence. Passive motion of the joints should be practised early and frequently to obviate ankylosis. Perfect results are, however, difficult to obtain, though improvement may be effected.

Forcible divulsion was employed by Little in one case. Under full anæsthesia the finger was forcibly straightened and the contracting tissues were ruptured; this was followed by the prolonged use of a splint, with good results except for some tendency to recontraction. In treatment of this kind in children care should be taken not to cause separation of the epiphyses of the phalanges.

In cases of extreme deformity and unsightliness amputation has been proposed and actually performed.

General Palmar Induration.—Cases are frequent in which the skin and subcutaneous fibrous tissues of the palmar surface of the hand and fingers are generally hardened, indurated, and slightly contracted, so that the fingers are held slightly flexed or arched on their metacarpophalangeal and phalangeal articulations, and are not easily capable of full extension. This condition is common in hard manual workers, as the result of occupation irritation. It is also occasionally exhibited by old and senile persons, in whom the skin may not be abnormally hardened, but in whom the fingers or some of them (especially on the ulnar side) are somewhat flexed by, apparently, a slight general shortening of the palmar fascias. This may develop as a senile change, without antecedent occupation irritation.

Trigger Finger.

Also called spring finger, snap finger, jerk finger, stuck finger, doigt à ressort (French), schnellender Finger, federnder Finger (German), digitus recellens. Trigger finger is a condition in which a finger during flexion or extension, or both, is suddenly arrested in its movement, and then after the exercise of extra force is suddenly released and completes the movement of flexion or extension with a sudden jerk, resembling the action of a trigger or blade of a pocket knife.

This affection was first described in 1850 by A. Notta. Since then about a hundred and thirty or a hundred and fifty cases have been recorded and a comparatively voluminous literature on the subject been produced.

The characteristic feature of the disease is the impediment to motion, the abrupt arrest of movement of the finger and its subsequent trigger-like release and sudden completion of movement (the "ressort"). The arrest always takes place at a certain point and angle, and may occur during flexion alone, during extension alone, or more frequently during both. Up to the point of arrest flexion and extension proceed normally, but at that point the motion is abruptly arrested and the finger seems to become set or locked at a sharp angle, often an acute or right angle. Then by an extra muscular effort the finger is suddenly released and completes its movement of flexion or extension with a sudden sharp jerk. The muscular exertion required to free the finger varies, sometimes requiring extreme effort, or even assistance from the other hand; one patient had to sit on the finger before the movement could be accomplished. At the instant of release a distinct click or sound can often be heard. Flexion is usually (though not always) more easily accomplished than extension, owing partly to the greater strength of the flexor muscles.

Pain, variable in degree and location, usually occurs associated with the condition, though exceptionally it is absent. In intensity it ranges from slight to excruciating. It is most severe at the time of the "ressort," but in some cases is excited by any movement of the finger. Tenderness on pressure may also exist. The seat of maximum pain is usually in the vicinity of the metacarpophalangeal articulation, but it may extend into, or be felt in, other parts of the finger, the hand, or even the forearm. Occasionally there is crepitation on movement of the flexor tendons, and various paræsthesiæ have been observed, especially in the earlier stages of the affection.

In the great majority of cases (upward of seventy-five per cent.) a nodule can be plainly felt on the flexor tendon of the finger, and movable with it, being manifestly attached to the tendons. This is in almost all cases situated near the metacarpophalangeal articulation, but in three or four cases such a nodule has been observed over the proximal or distal interphalangeal joint. In a very few cases a similar nodule has been perceptible, but did not move with the tendon, being connected with the tendon sheath. The nodosity plays an important part in the mechanism of the affection; still, in numerous cases it is not to be felt. The impediment to motion is sometimes overcome by pressure on the node; also by manipulation of the distal phalanx.

The affection is uncommon. It may occur at any age, having been reported at the age of three months (regarded as congenital), seventeen months, and two years, up to ninety years. It is much the most frequent in the adult period, however, from twenty to seventy years of age. It occurs in females rather more frequently than in males, in the proportion of about three to two. A similar trigger condition has been observed in the toes, knees, and other joints, and also in animals; and one or two cases have been reported in which lateral movements of the fingers exhibited the same kind of impediment.

Usually one finger alone is involved, but more than one may be affected, either at the same time or in succession. In one case all the fingers of both hands were involved. In some cases the abnormality occurs symmetrically on both hands. Of the two hands the right is much the more liable to the affection, being involved in over twice as many cases as the left hand.

The middle finger, ring finger, and thumb are the ones much the most subject to the affection, in about the order named; the index and little fingers are much less frequently affected. In the left hand, the thumb and middle finger suffer less frequently than they do in the right hand.

V. Carlier, who in 1889 collected 105 cases of trigger finger, gives the following statistics as to the number of times each finger was affected:

	Right hand.	Left hand.	Total.
Middle finger	32	9	41
Ring finger	20	18	38
Thumb	26	7	33
Little finger	6	3	9
Index finger	8	1	9
	92	38	130

The joint at which the trigger condition is chiefly manifested is the interphalangeal articulation of the thumb and proximal interphalangeal joint of the other digits, the second phalanx in the position of arrested movement being flexed on the proximal phalanx. Sometimes, however, the distal interphalangeal joint is the one involved; rarely the metacarpophalangeal articulation.

The chief conditions associated with trigger finger as etiological factors in the reported cases are occupation, traumatism, rheumatism, and neurotic temperament.

The factor cited as causative of the condition in the greatest proportion of cases is occupation irritation, as in seamstresses, soldiers, brushmakers, etc. Pressure upon or irritation of circumscribed portions of the palm is supposed to cause the tendinous and other lesions that are responsible for the trouble. Thus, in the case of a tennis player the pressure of the racquet handle in the palm was supposed to have caused the development of a tendinous nodule that produced the trigger condition. This effect of occupation irritation is held to explain the greater liability of the right hand to the disease. Another explanation of the effects of occupation attributes the trigger condition to the excessive use of single fingers, in much the same manner as writer's cramp and other occupation neuroses are produced.

A considerable proportion of the cases originate distinctly from traumatisms of the affected part, the injuries producing the particular inflammatory or other lesions necessary to set up the trigger condition. Many cases have with greater or less probability been attributed to rheumatism and lesions of rheumatic nature, while the upholders of nervous theories of the affection state that neurotic conditions predispose to it.

It may be concluded that traumatisms and occupation irritation certainly, and perhaps rheumatism, are capable of producing trigger finger; but in some cases, as those in children and the bilateral cases, other causative factors must operate.

The disease usually has a gradual onset, varying in symptoms and duration. The cases produced by traumatism develop most rapidly, within a few days or two or three weeks after the injury. Other cases develop more slowly, over a period of weeks and months and even of years. The initiatory symptoms may be a slight inconvenience or awkwardness in movement of the finger; this difficulty gradually increases to the fully developed trigger condition. Vague pains appear in the affected part, increasing in intensity. Sometimes a rustling or grating movement of the flexor tendon is early felt, resembling the crepitation of tenosynovitis. In other cases paræsthesiæ early appear in the region involved, as numbness, "going to sleep," formication.

The anatomical cause and mechanism of trigger finger have given rise to considerable discussion, and various explanations have been presented.

Most of the cases are undoubtedly due to lesions of the flexor tendons or their sheaths, especially those in which the nodule is perceptible. This nodule is in most cases attached to the tendon, near the metacarpophalangeal joint; it is of inflammatory, fibrous, or neoplastic (fibromatous, osteomatous, etc.) origin. As the tendon moves the nodule is caught at some point, as in transverse bands of the fascia or in constricted portions of the tendon sheath, so that motion is suddenly arrested; by further effort the nodule is forced past the obstruction and the movement is completed rapidly by the excessive muscular tension.

In a few cases it has been demonstrated that the lesions causing the trouble were situated in the tendon sheath, the tendon itself being normal. These lesions consist either of an annular or circumscribed constriction of the sheath, a thickening of the sheath, or a nodular growth in it, which interfere with the movements of the tendon within. Such lesions can be produced by inflammation, neoplasms, etc. In these cases a nodule may or may not be felt, but if present it does not move with the tendon. There may also be lesions of both the sheath and the tendon.

Thickening or stiffening of the synovial sac in such a manner as to interfere with its gliding to-and-fro movement between the tendon and its sheath has been advanced as a cause of trigger finger, and may possibly be a factor sometimes. Intrasynovial floating bodies have also been suggested as a cause of the trouble.

Some authorities have considered abnormal conditions in the phalangeal articulations to be capable of causing trigger finger. The particular abnormalities that have been mentioned in this connection are (*a*) abnormal configuration of the joint, (*b*) short lateral ligaments, and (*c*) projections at the side of the joint. It is conceivable how a certain surface configuration of the joint, as a projecting nodule or ridge or abrupt curvature, could produce a trigger-like action. Shortened lateral ligaments would obstruct the motion of the phalanx at a given angle; but if the ligaments were sufficiently elastic to stretch enough to permit the phalanx to pass beyond the obstruction, the resiliency of the ligaments as well as muscular action would cause a quick jerking completion of the movement. The possibility of such a trigger action of short lateral ligaments I have been able to demonstrate in a dissection of a hammer finger. Bony projections at the side of a joint, by becoming engaged in the lateral ligaments, might also cause an impediment to motion. It is easily conceivable how articular changes of the character mentioned could cause a sort of trigger finger, and it is possible that they may exceptionally be the cause of the condition.

That some cases of trigger finger are of nervous origin and due to muscular spasm has been upheld by a few writers, especially Carlier. Thus, it is supposed that during extension the middle phalanx is suddenly arrested by spasm of the flexor sublimis digitorum; then more energetic contraction of the extensor muscle overcomes this spasm with a jerk. Arrest during flexion is attributed to a momentary impotence of the flexor or perhaps spasm of the extensor, which is followed by brusk contraction of the flexor. According to some views trigger finger is somewhat allied to writers' cramp and similar occupation neuroses, arising in various occupations requiring excessive use of particular fingers. While muscular spasm cannot be a common cause of real trigger finger, yet the affection may perhaps occasionally be of spasmodic nature.

The prognosis of trigger finger is generally favorable. Spontaneous recovery sometimes occurs, and the affection is quite amenable to treatment, though sometimes no improvement is obtainable.

Treatment of non-operative kind often produces good results, especially in the early stages of the affection. One of the most essential parts of the treatment is rest, by immobilization of the part on a splint. Counter-irritants like tincture of iodine, massage, electricity, poultices, etc., are also useful. In inveterate cases operation is necessary. The seat of the trouble should be cut down upon; the nodule on the tendon or sheath should be removed and the sheath of the tendon should be slit open at any constricted portion. Simple incision of the tendon sheath in obscure cases may result in cure.

CIRCULATORY DISORDERS.

The distance of the hands from the heart gives rise to a relative weakness of the circulation in this member, which may become manifest whenever from cardiac or other causes there is a general lowering of the tone of the circulation. The feet suffer from the same cause, and even more than the hand, since in the lower extremities the effect of gravity is an additional embarrassment to the circulation. The hand may also suffer from obstructions anywhere in the course of the vessels of the upper extremity.

Congestion of the hand is frequent in heart disease and other conditions in which the circulatory forces are weakened. The hand is cold, slightly swollen, either dry or clammy, of a purple color; on pressure the blood is forced out, leaving a white spot into which the blood slowly returns after the pressure is removed. The congestion is also diminished by elevation of the hands. Hyperidrosis or excessive sweating is another consequence of weakened blood pressure or lowered vascular tone. Œdema of the hands is common in conditions of general anasarca or under circumstances similar to those causing passive congestion. In systemic affections such vascular disturbances are bilateral; but where the obstruction to the circulation is local, as in trauma, obstructed vessels, aneurism, etc., of one side, the stasis or œdema is unilateral. Gangrene may be an extreme result of vascular obstruction. Clubbed or Hippocratic fingers in cases of cardiac and pulmonary disease may be partly due to passive congestion, partly to real trophic alterations. Angioneurotic œdema may occur on the hand. The treatment of these conditions is that of their cause.

MUSCULAR AFFECTIONS.

The lesions of the muscles of the hand chiefly met with are the atrophies, paralyses, spasms, etc., caused by nervous lesions, considered below. Primary diseases of the muscles are rare here as elsewhere.

Unopposed action of a set of muscles, as after section of the tendons or paralysis of the opposing group, causes corresponding contractures.

Rarely the flexor muscles of the forearm are relatively shortened by arrested development. This causes a flexion of the fingers, not paralytic or spastic in character, but due entirely in a mechanical way to the shortness of the muscles and their tendons. It is manifested by inability to extend the fingers; strong flexion of the wrist, by relaxing the tendons, increases the range of extension of the fingers. The condition may develop alone without the coexistence of other abnormal conditions elsewhere, and becomes manifest during the growing or preadult period; it may also occur in infantile paralyses with other lesions. Attempt may be made to remedy the condition by division or plastic lengthening of the tendons.

Occupation muscular atrophy is an atrophy gradually developed in groups of muscles by continual use or overuse incident to the occupation pursued. It has been observed in the hand and elsewhere in a few cases. It affects especially the thenar muscles in lapidaries and others, and also the hands of writers. It is regarded as more of myopathic than neuropathic origin, and is quite amenable to treatment by rest, electricity, tonics, etc.

Ischæmic myositis or *paralysis* occasionally affects the hand from prolonged anæmia of the muscles of the forearm and hand, caused especially by pressure in this region from the use of tight bandages and splints. The long-continued anæmia causes degenerative and inflammatory changes in the muscle tissue, and sometimes induration and contraction of the muscle. It is manifested by pain, swelling, impaired movement, and sometimes contractions of the hand. The condition should be prevented as far as possible by proper treatment of fractures of the forearm. When developed it can usually be overcome by massage, exercise, electricity, douching, etc.; but sometimes it results in permanent paralysis, contractures, and deformity.

Myositis (suppurative, tuberculous, syphilitic, interstitial, rheumatic, etc.) and gummata or other tumors in the muscles are rare causes of impairment of motility. After such inflammatory conditions contractions from shrinking of the endomysial tissue and cicatrices may result. With ossifying myositis are often associated ankylosis of one or another joint of the thumb, smallness of the thumb, slight deflection of the thumb, and impairment of its motion.

Occupation or *habit contractures* sometimes occur in those whose occupation requires the hand to be held or exercised or overused in prolonged or habitual positions, as a flexion of the fingers in drivers, etc. Such cases demand change of occupation and appropriate local treatment.

NERVOUS AFFECTIONS.

The hand suffers severely and conspicuously in many nervous diseases, and so marked and characteristic are its functional and structural changes that its condition affords data valuable for diagnosis in various nervous affections. The primary nervous lesions causing the changes in the hand are seated in the nervous centres or in the nerve trunks of the upper extremity; only rarely in the hand itself, as in inflammation or injury of the nerves in the hand, or, perhaps, in occupation neuroses.

The functional and structural changes of neuropathic origin to which the hand is subject may be classified as follows:

1. Sensory disorders: Pain; disorders of common sensation.
2. Motor disorders: Paralysis; tonic spasm, contractures, etc.; clonic spasm, tremor, etc.; ataxia.
3. Trophic changes: atrophies, arthropathies, dermatoses, necrosis, etc.
4. Vascular phenomena.

These changes and symptoms do not usually exist singly, but the condition actually presented in given cases is ordinarily a mixture of various classes of symptoms, one nervous disease producing a complex of phenomena.

Pain or neuralgia in the hand occurs in connection with numerous conditions, as in neuritis, locomotor ataxia, Raynaud's disease, etc., besides being a result of gouty, rheumatoid, and inflammatory conditions.

The *disorders of sensation* of the hand include hyperæsthesia, paræsthesiæ, and especially local anæsthesia or hypæsthesia caused by injuries or lesions of the brachial plexus or its branches, besides more general and irregular anæsthesias from central nervous disease. In given nervous lesions sensory disturbances are usually less intense and more quickly recovered from than the corresponding motor paralyses.

Paralysis of any or all of the groups of muscles pertaining to the hand occurs in general paralytic conditions, as hemiplegia, anterior poliomyelitis, progressive muscular atrophy, and numerous others, and in inflammations or injuries of the nerves of the upper extremity. With the paralytic condition is usually associated atrophy, often extreme, of the affected muscles.

The primary effect of any paralytic condition is loss of the corresponding muscular function. Secondarily, from the unopposed action of the muscles antagonistic to the paralyzed muscles, or from the unequal degree in which different groups are affected, muscular *contractures* arise, which may cause various deformities. The contractures are at first of the nature of continuous or tonic spasms, and can be overcome by passive force. Ultimately the prolonged malposition causes vicious secondary alterations and ankylosis in the joints, with atrophic changes or arrested development in various structures resulting in disproportionate relations of the various parts of the member, so that finally the deformity becomes permanent and uncorrectible. Different nervous diseases produce different characteristic deformities of the hand, as the "claw hand" of ulnar paralysis, the "wrist drop" of musculo-spiral paralysis, the "preacher's hand" of cervical pachymeningitis, the club hand of infantile paralysis. *Tonic spasms* of the hand, not associated with paralysis, occur in tetany, tetanus, hysteria, and Thomsen's disease.

Some nervous affections are manifested in the hand by *tremors* and *clonic spasms*, as in multiple sclerosis, paralysis agitans, athetosis, chorea, epilepsy.

Ataxia, or inco-ordination of the movements, may affect the hands as a part of the symptom-ensemble of various central nervous diseases, as in multiple sclerosis, locomotor ataxia, general paresis, Friedrich's ataxia. The occupation neuroses are also largely manifested by ataxic phenomena. The inco-ordination is manifested by difficulty or inability to perform delicate movements or by spasmodic movements on attempting voluntary actions, and is not necessarily associated with any paralysis or decrease of motor strength.

Trophic changes in the hand resulting from morbid nervous impressions may cause great damage, and exhibit considerable variety, as muscular atrophies, skin changes, onychias, joint changes, ulceration, necrosis, hypertrophies. Atrophies of various muscles of the hand, in connection with paralytic and spastic phenomena, are characteristic, severe, and conspicuous lesions in various affections, as progressive muscular atrophy, nerve injuries, and other conditions. Trophic changes in the skin and nails occur, as in the condition termed glossy skin. In many paralytic conditions of the hand the skin is pale, cool, rather smooth, and exhibits a tendency to desquamation; and the subcutaneous tissues are slightly œdematous. Trophic changes in the joints occur rarely, exemplified by Charcot's arthropathy in locomotor ataxia. General hypertrophy of the hand has been noted in a few cases of syringomyelia. Dermatitis, the formation of vesicles and blebs, ulceration, and even necrosis of circumscribed areas occur in syringomyelia, the neuritis of leprosy, Raynaud's disease, and other conditions. In nervous diseases arising during the period of growth, as infantile paralysis and infantile palsies, arrested and irregular development may contribute toward contracture and deformity in later years.

Vascular Phenomena—flushing, pallor, etc.—occur in Raynaud's disease, erythromelalgia, hysteria, and other conditions.

Having briefly summarized the neuropathic functional and structural changes to which the hand is subject, the effects upon the hand of the various nervous diseases remain to be considered.

Occupation Neuroses.—These comprise a class of local functional nervous disturbances produced by the excessive use of definite groups of muscles in performing delicate and complicated actions necessitated in various pursuits, to which the hand from its usage is subject. These affections are characterized by tonic spasms or cramps, tremors, inco-ordination and ataxia, or pain, which are brought on when attempts are made to perform the habitual actions, so that these movements can be executed only with difficulty or not at all. As a rule, other acts requiring equal delicacy and complexity of co-ordination can be performed with ease, the neurosis operating only against the particular movements that produced it. The occupation neuroses present no menace to life or the general health, but they are financially and psychically serious in that they may prevent their subjects from continuing in their accustomed avocation.

No anatomical changes have been demonstrated in these cases. Neuritis is sometimes present, but it is a complication and not an essential feature. The condition is a functional motor disorder and is sometimes styled a local neurasthenia. The affection may develop at any adult age; it is rare under twenty, a large proportion of cases develop between twenty and thirty, and many from thirty to fifty years. Occupation neuroses may attack persons in excellent physical condition, though those of a neurotic tendency or debilitated state are more subject. They develop insidiously, the first symptoms being a certain amount of stiffness, tremulousness, uncertainty, jerkiness, dull aching pain, fatigue, or weakness, during the acts at fault. These troubles slowly increase, until the neurosis is fully established, when on attempting to execute the customary movements the hand is seized with a cramp or tonic spasm, or involuntarily goes into jerky spasmodic or choreic movements, or its movements cannot be co-ordinated, or it becomes tremulous, or paretic, or the seat of a deep dull aching pain. The affection is chronic in its course. The prognosis is unfavorable so far as cure is concerned, as the neurosis is very difficult or impossible to eradicate. The symptoms can be easily ameliorated by rest and change of occupation, but even after long intervals the trouble almost invariably recurs upon resumption of the occupation that caused it.

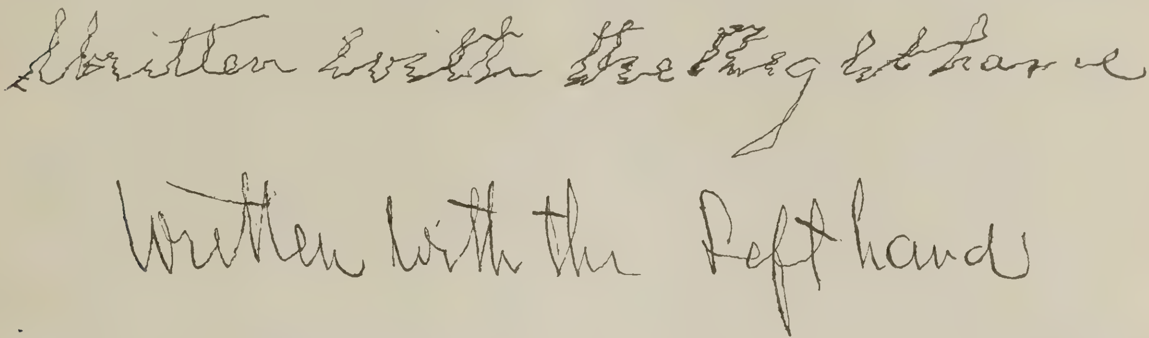
Written with the right hand
Written with the left hand

FIG. 2511.—Handwriting in a Case of Writers' Cramp (Tremulous Variety) of the Right Hand. The patient was a clerk and had been a good penman with the right hand; after the invasion of the neurosis he learned to write with the left hand. (Original.)

The commonest and best known of the occupation neuroses is *writers' cramp*, which typifies the whole group. Analogous neuroses occur or have been observed in connection with many other occupations, of which the commonest are telegraphers' cramp, typewriters' cramp, musicians' (pianists', violinists') cramp, sewers' cramp, hammer cramp.

The diagnosis of well-marked cases of occupation neuroses usually presents no difficulty. The earlier stages may not be easily distinguishable from the vague incipient symptoms of other nervous affections. A local neuritis may present symptoms simulating occupation neuroses; but in neuritis the motor or ataxic trouble is not so closely related to one particular set of movements, and the electrical reactions may be altered. The prognosis of neuritis is also more favorable.

If symptoms of approaching writers' cramp appear, prophylactic treatment is important. The act of writing should be made as comfortable as possible, by the use of an easy-writing pen (as a gold pen), a penholder that can be held with ease, smooth paper, and the adoption of such arrangements and position as are easiest for writing. The pen should be held lightly and grasped with as little force as is possible. The manner in which the penholder is held by the fingers should be changed. New sets of muscles should be brought into play, and the motions of writing should be altered as much as possible and carried on with the entire hand and forearm rather than with the fingers alone.

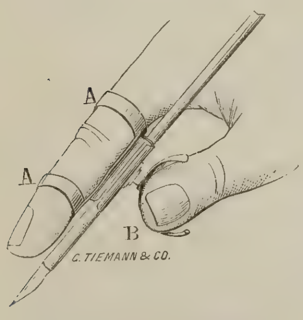

FIG. 2512.—Mathieu's Apparatus for Writer's Cramp. (After Dana.)

The best treatment of incipient or fully developed occupation neuroses is rest and suspension or change of the occupation. The symptoms readily yield to such treatment, but unfortunately these measures are not always practicable. General neurotic or debilitated conditions should receive appropriate treatment. Local massage, gymnastics, and electricity are useful. The unaffected hand may be used, after practice and training, to execute the movements impaired in the other hand, though in such cases the second hand often becomes itself affected by the neurosis. Various forms of apparatus have been devised for use in writers' cramp, for immobilizing the fingers involved, for holding the penholder and so relieving the fingers of the effort of pen-prehension, and for bringing new muscles into play in the act of writing (Figs. 2512, 2513). Such devices may be of service in these cases, but the substitution of type-writing machines for the pen would be far more efficacious.

Diseases and Injuries of the Nerves.—Inflammation of the nerves supplying the hand presents the usual phenomena of neuritis, tenderness over the affected nerve, pains, hyperæsthesia, hypæsthesia, or paræsthesia of the area supplied, motor paralysis, trophic changes, altered electrical reactions. The symptoms vary in their character, location, and intensity in different cases and in different varieties of the disease, as in the traumatic, multiple, rheumatic, gouty, toxic (lead, alcohol, etc.), leprous, and other forms of nerve disease. Neuritis sometimes exists with and complicates occupation neuroses; and an occupation neuritis may be induced in the member by the occupation pursued. Degeneration of the nerves produces corresponding paralytic, spastic, and trophic phenomena.

In chronic *lead poisoning* the extensor muscles of the hands are often paralyzed, producing the "wrist drop" characteristic of this condition; sometimes there is also in plumbism a swelling or ganglion on the back of the wrist. In *alcoholic polyneuritis* wrist drop may also occur, but less frequently than foot drop.

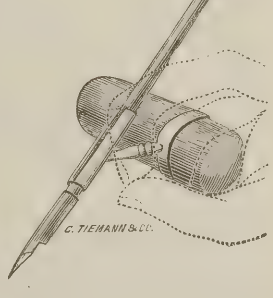

FIG. 2513.—Apparatus for Writers' Cramp. (After Dana.)

Injury or disease of the *brachial plexus*, produced by rheumatic inflammation, by rheumatoid disease of the cervical vertebræ, in connection with dislocations of the shoulder, from the pressure of crutches, or other causes, results in motor paralysis, contractures, sensory disturbances, muscular atrophies, and other trophic changes, corresponding to the manner and extent in which the cords of the plexus are involved.

In division or other causes producing paralysis of the *musculo-spiral nerve,* there is paralysis of all the muscles on the posterior aspect of the forearm and the radial group of muscles, so that the wrist and proximal phalanges of the fingers cannot be extended, and the hand falls limply; this constitutes the condition of "wrist drop" which is a characteristic phenomenon in lead poisoning and other nervous affections. The middle and distal phalanges remain capable of extension from the action of the interossei and lumbricales muscles, which are innervated by the ulnar nerve. The paralyzed muscles may atrophy. Sensation may be lost on the radial portion of the dorsum of the hand, usually over the area corresponding to the thumb, index and middle fingers, and radial half of the ring finger; individual variations in the distribution of the nerves of cutaneous sensation in the hand are, however, frequent.

The *median nerve* furnishes cutaneous sensation to the palmar aspect of the thumb, index, middle, and radial half of ring finger, and innervates the pronator muscles, flexor carpi radialis, flexor longus pollicis, flexor sublimis digitorum, radial half of flexor profundus digitorum, abductor pollicis, opponens pollicis, outer head of flexor brevis pollicis, and the two outer lumbricales. Paralysis of the median nerve produced by section of it above the elbow or other cause results in loss of sensation over the area mentioned, atrophic changes in the muscles of the forearm and the thenar eminence, loss of power of abduction and opposition of the thumb, loss of flexion of last phalanx of the thumb, diminished power of flexion of the proximal phalanx of the thumb, and impairment of flexion especially of the index and middle fingers. The power of pronation is lost and the wrist is flexed only by the flexor carpi ulnaris.

Division of the median nerve at the wrist, below the separation of the branches to the muscles of the forearm, results in loss of power of abduction and opposition of the thumb.

Paralysis of the *ulnar nerve* causes loss of sensation over the ulnar third of the hand and over the little and ulnar half of the ring finger, anteriorly and posteriorly, loss of motor power of the muscles supplied by it (flexor carpi ulnaris, ulnar half of flexor profundus digitorum, the muscles of the little finger, the two ulnar lumbricales, all the dorsal and palmar interossei, adductor pollicis, and inner half of flexor brevis pollicis), together sometimes with atrophic changes, at times extreme, in the muscles affected. Adduction of the thumb and lateral movements of the other fingers are abolished; flexion of the proximal phalanges is interfered with, and these phalanges are held in extension or superextension. From paralysis of the interossei and two lumbricales extension of the middle and distal phalanges is lost or impaired, and these phalanges, especially in the little and ring fingers, are held strongly flexed. The action of the flexor carpi ulnaris is lost. In closing the fist, the distal and middle phalanges are first flexed by the common flexors, and then the proximal phalanges are bent by the continued action of these muscles.

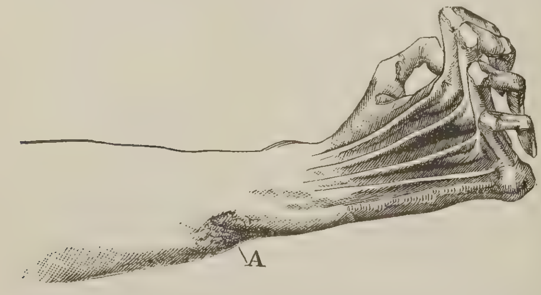

FIG. 2514.—Extreme Atrophy and Contractures from Paralysis of Ulnar Nerve (Caused by Wound at A); an Extreme Instance of "Claw-hand." (Duchenne.)

When the injury or lesion involves the distal portion of the ulnar nerve, near the wrist, beyond the branches given off to the flexor profundus digitorum and flexor carpi ulnaris, these muscles will escape paralysis.

The deformity known as "claw-hand" (main en griffe) is produced by paralysis of the interossei and lumbricales, the common flexors and extensors being at the same time unparalyzed. As these muscles are (with the exception of the two radial lumbricales) supplied by the ulnar nerve, claw hand is a characteristic consequence of paralysis of the ulnar nerve, and occurs in injuries of that nerve (Fig. 2514), and sometimes in progressive muscular atrophy (Fig. 2517), amyotrophic lateral sclerosis, syringomyelia, leprous neuritis, and other conditions. The action of the interossei and lumbricales is to flex the proximal phalanges and extend the middle and distal phalanges, besides acting as abductors and adductors. Paralysis of these muscles results in a superextended position of the proximal phalanges (from the unopposed action of the extensors) and strong flexion of the middle and distal phalanges (from the action of the common flexors); this position of the hand is the one to which the term claw-hand is applied. Along with this paralytic and contractured condition, extreme atrophy of the paralyzed muscles is often present in claw-hand, the palm being hollowed out, and the interosseous spaces on the dorsum of the hand being sunken so as to form deep grooves.

Combined paralysis of the ulnar and median nerves, the musculo-spiral nerve being normal, results in the deformity known as the "preacher's hand" (main du prédicateur emphatique), from its supposed resemblance to the emphatic gestures of public speakers (Fig. 2515). The unopposed action of the extensor muscles causes the hand and proximal phalanges to be habitually held in a position of marked extension and superextension. The "preacher's hand" occurs especially in hypertrophic cervical pachymeningitis, though it occasionally appears in other nervous diseases.

Glossy skin is a rare trophic change sometimes resulting from wounds or other lesions of nerves, which affects the fingers especially. The digits, or one or two of them, are smooth, shining, and glossy, devoid of hair, pinkish or blotched as if by chilblains, and the surface of the skin lacks its natural linear markings. Trophic changes in the nails also occur. The lesions are the seat of burning pain and neuralgia.

Vaso-neuroses.—There are some allied conditions which along with prominent vascular phenomena present pronounced neuropathic features, and hence may be classed as vaso-neuroses. These are Raynaud's disease, erythromelalgia, chilblains, and the condition of vascular spasm described under the name "dead fingers." The hand, along with the foot, is a favorite seat for these affections, which are considered in full elsewhere and can be only briefly touched upon here.

Raynaud's disease (peripheral gangrene, symmetrical gangrene) is a rare condition characterized by small circumscribed areas of vascular disturbance or ischæmia, running on to gangrene, associated with severe neuralgic pains. The lesions are usually several in number, situated on the fingers or toes, sometimes the face; almost always they are bilateral and symmetrical, but the writer has seen a case involving one hand only. In the milder cases or earlier stages the lesions consist of small local areas of anæmia ("local syncope") or of passive congestion ("local asphyxia"). In the severer cases circumscribed moist black gangrenous patches develop; after the slough separates an ulcer is left that heals very slowly. The course of the disease is very slow and protracted, the lesions requiring weeks or months for their evolution and repair. The necrotic process has been known to cause complete spontaneous amputation of the ends of the fingers. In treatment, analgesics are required for the relief of pain, and tonics or other measures for improving the general condition. Local treatment aims at promoting the separation of the slough and stimulating the healing process; this is accomplished by poultices, caustics (silver nitrate, copper sulphate), excision of the sloughs, antisepsis, etc.

Erythromelalgia is an uncommon condition affecting usually the feet, but also the hands and rarely other regions. The disease is manifested by recurring paroxysms, though sometimes the trouble is almost continuous. The attacks consist in the development of areas of intense burning, pain, and tenderness on the feet or hands, associated usually with transient redness or congestion of the hyperæsthetic area. The attacks are brought on or aggravated by warmth, dependent position, and exertion. The pain is frequently so excruciating as to cause complete disability of the extremity affected. Erythromelalgia is usually classed with nervous diseases, though it can perhaps be equally well ranked as a circulatory disorder—a vaso-motor neurosis or vascular hyperæsthesia. Distance from the heart is a factor in causing, and determining the location of, the lesions; and gravity is another factor contributing to ischæmia which probably accounts for the preference for the feet which the disease exhibits. The disease is obstinate and persistent and no effective treatment is known. During the paroxysms relief is usually afforded by elevation of the part, the application of cold (immersion in ice water), and rest.

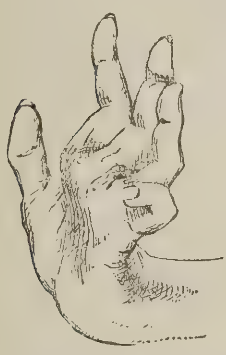

FIG. 2515.—Characteristic Position of the Hand in Hypertrophic Cervical Pachymengitis—the "Preacher's Hand." (Meillet and Richer.)

Chilblains (pernio) are often regarded as related to frostbite, but in some respects they resemble Raynaud's disease and erythromelalgia, and are probably a form of vaso-neurosis. While they sometimes originate after exposure to cold, this is not always the case; anæmic and chlorotic individuals are especially subject. Chilblains are commonest on the feet, but sometimes occur on the hands. The disease is obstinate and the attacks persistently recur, especially in winter. The attack consists in a severe itching or burning pain and tenderness in the areas affected, which are red and erythematous. The pain is aroused or aggravated by warmth, especially by warmth following exposure to cold. In severe cases the affected areas may become œdematous and bullous, and undergo ulceration. For relief of the pain, very hot or very cold water may be applied; also astringent or sedative ointments or lotions, etc. Constitutional treatment should be directed against any anæmic, chlorotic, gouty, or rheumatic conditions.

Vascular Spasm.—In the rare condition sometimes termed "dead finger" one or more fingers undergo sudden, repeated, and transient vascular spasm, so that they become white, bloodless, and cold. The paroxysms last a few minutes, hours, or even days. At times the blanching is preceded by lividity, and is occasionally accompanied by dull pain. The affection was first described by Allan McLane Hamilton in 1874, and since then a few cases have been reported. The treatment is by galvanism, nitroglycerin, or other vaso-dilators.

Acrodynia is a disease of the Orient, occasionally occurring in Europe, characterized by pains in the hands and other extremities, with erythema, thickening and exfoliation of the epidermis, pigmentation, and other changes in the skin.

Hypertrophic Cervical Pachymeningitis.—In this affection the upper extremities are especially involved, usually one becoming affected after the other. In the period of development of the disease there are pains and altered sensation in one or both hands. After the cervical lesions are fully established marked paralytic and atrophic changes develop. The particular distribution of these lesions varies in different cases, but the commonest and most characteristic condition is a paralysis and atrophy of the muscles supplied by the ulnar and median nerves, leaving the musculo-spiral group less involved. The flexors and pronators and the muscles in the palm are paralyzed and atrophied. The unopposed action of the extensors brings the hand and fingers (especially the proximal phalanges) in a position of superextension, forming the so-called "preacher's hand," already referred to; this position is quite characteristic of cervical pachymeningitis, though it may occur in other affections (Fig. 2515). At first the hand can be flexed passively, but later the extensor muscles may undergo contracture. Sensation may be lost or impaired in the affected areas.

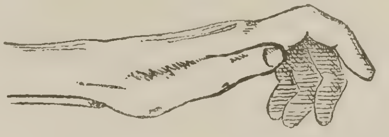

FIG. 2516.—Characteristic Appearance of the Hand ("Ape Hand") in Progressive Muscular Atrophy. (Meillet and Richer.)

Cervical Paraplegia.—In injuries or myelitis of the upper part of the spinal cord the upper extremities may be more or less completely paralyzed, with extensive muscular atrophy.

Progressive Muscular Atrophy.—The hands suffer early, characteristically, and severely in this disease, either successively or simultaneously. The muscles of the thenar eminence are usually the first to be affected; they gradually become atrophied and paralyzed, producing a peculiar flatness of this region. The hypothenar muscles soon become similarly involved. At this stage the hand appears long, thin, and flat, and the thumb lies parallel and in the same plane with the other fingers; the hand in this condition has been likened in appearance to that of the ape (Fig. 2516).

Later the interossei and lumbricales atrophy and become paralyzed, resulting in corresponding loss of the power of abduction and adduction of the digits, flexion of the proximal phalanges, and extension of the middle and distal phalanges. If the flexor and extensor muscles in the forearm are at this stage unaffected, "claw hand" will result (Fig. 2517), though, as the muscles of the forearm usually become involved early, this deformity does not very often occur in progressive muscular atrophy.

Fibrillary contractions occur in the affected muscles. Contractures are not usually present to a marked degree.

Anterior Poliomyelitis.—In infantile paralysis the upper extremity is sometimes involved, but much less frequently, especially permanently, than the lower. Paralysis of irregular and varying distribution occurs, with atrophy of the affected muscles and of bony and other tissues, contractures of the opposing muscles, and retardation of growth. The most injurious and the most characteristic consequences of the disease in infants are the deformities, produced by arrested and irregular development of the parts, that make their appearance as the growth of the child proceeds. In this way, from contractures and irregular development at the wrist, various forms of club hand may be produced.

In the adult form of the disease, permanent paralyses, atrophies, and contractures may delop, but as full growth has been attained the ultimate deformity is less than in infants.

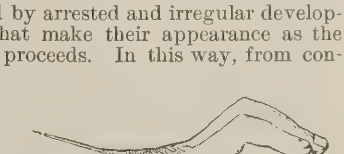

FIG. 2517.—Claw Hand of Moderate Degree in Progressive Muscular Atrophy. (Meillet and Richer.)

Locomotor Ataxia.—In this disease the hands often suffer from want of co-ordination and inability to perform delicate movements, like picking up a pin or buttoning the clothing. Rarely trophic changes, as of the nails, occur in the hand. Charcot's arthropathy occurs rarely in the wrist or joints of the fingers; in this condition an enlarged phalanx may present an appearance similar to that of syphilitic dactylitis. Hyperæsthesia sometimes occurs about the fingers.

Lateral Sclerosis.—In this condition the upper extremities are usually affected much less and much later than the lower, though rarely the disease begins in the upper extremities. There are present paresis, muscular tension, and exaggerated tendon reflexes; the wrist and fingers are usually strongly flexed and the arm is adducted.

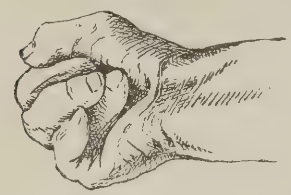

FIG. 2518.—Hemiplegic Contracture of the Fingers. (Meillet and Richer.)

Amyotrophic Lateral Sclerosis usually begins in the upper extremity, with paralysis, muscular atrophy, fibrillar contractions, pain, and paræsthesia, followed at a later stage by muscular rigidity and contractures. Sometimes the fingers are bent into the palm and the wrist is flexed; sometimes there is atrophy of the interossei and claw hand.

Multiple Sclerosis.—The most conspicuous symptom exhibited by the hand in this condition is the intention tremor, or rapid rhythmic tremor when voluntary movements are attempted. The wrist jerk is exaggerated, and paresis and muscular rigidity may be present. Trophic changes in the hand occasionally occur, as swelling of the small joints of the fingers, atrophy of the small muscles, blebs, onychia, sweating, lowered temperature.

Syringomyelia (Morvan's disease) involves especially the upper extremities, and is manifested by paralysis and atrophy of muscle groups, varying in situation, paræsthesiæ and anæsthesia (especially to temperature and pain) in irregularly distributed patches, and trophic changes. Some cases of syringomyelia simulate progressive muscular atrophy, beginning with atrophy and paralysis of the thenar, hypothenar, and interosseous muscles of the hand, producing claw hand; the paralysis later proceeds up the forearm. Enlargement of joints (frequently the wrist) occurs, similar to Charcot's tabetic arthropathy. Œdema, vesicles, bullæ, ulcers, onychias, recurring painless whitlows, and even extensive gangrene and mutilation about the fingers and hand may occur. In a few instances general hypertrophy of the hand has been observed, and in a few others Dupuytren's contraction has been present.

Hemiplegia.—In this affection the primary condition manifested in the hand is paralysis. Later, especially following secondary descending degeneration in the spinal cord, contractures may develop, usually of the flexor muscles (Fig. 2518), though the extensors may be shortened. The muscles are only exceptionally atrophied, aside from decrease in size caused by disuse.

Infantile cerebral palsies and *infantile hemiplegia*, occurring especially during the first two years of life and arising from labor traumatisms (birth palsies) or pathological cerebral conditions, usually affect the upper extremity worse and more permanently than the lower. Trophic effects which cause permanent damage follow the primary paralysis. Growth of the parts involved is arrested or irregular, so that the hand and arm are small and undeveloped, less in size than their fellow, and often deformed from contractures, disproportionate development of different parts, or secondary joint changes. The fingers, wrist, and forearm are usually flexed, and forms of club hand may be produced. Frequently the affected member remains the seat of ataxia, chorea, tremor, or the peculiar motor disorder called athetosis (see below). About ten per cent. of the cases of infantile hemiplegia are followed by athetosis, which is a sequela of this condition rather more frequently than of birth palsy and much more frequently than of adult hemiplegia.

Friedrich's Ataxia is a rare hereditary condition, occurring chiefly in children, in which the hands become involved by extension of the disease from the lower extremities. The hand exhibits an ataxic condition, delicate movements like buttoning the clothes being interfered with. "Manus cavus" often occurs, the palm being arched; the proximal phalanges may be superextended and the middle and distal phalanges somewhat flexed, producing some tendency to claw hand.

In *general paresis* the hands may exhibit anæsthesia, paralysis, tremor, and lack of co-ordination, shown especially by impaired ability to execute delicate movements, as writing.

In *tetanus* the hand participates in the tonic and clonic spasms. As the flexors are stronger than the extensors, in this as in many other spastic conditions the position of the fingers and hand is usually that of firm flexion.

Tetany affects the hands conspicuously. Intermittent paroxysms of tonic muscular spasms occur, associated with pain and paræsthesia. The paroxysms last for from a few minutes to a few days and may persist even during sleep; the intervals between the paroxysms last from hours to months. The mechanical and electrical irritability of the muscles is increased, and pressure on the nerve trunks and arteries excites an attack (Trousseau's symptom). The position assumed by the hand during the spasm depends on the group of muscles affected, but is usually one of flexion. Often the hand assumes the conical shape of the accoucheur's hand about to be introduced into the vagina; the fingers are flexed at the metacarpophalangeal joints and extended at the other joints, the hand is narrowed and the thumb adducted. Sometimes the fist is forcibly closed by general flexion, the thumb being pressed into the palm and the other fingers flexed upon it. Rarely the fingers are extended and separated.

Thomsen's Disease (congenital myotonia) is a rare hereditary affection, manifested by the occurrence of tonic spasms on attempting voluntary movements. The hand may be involved with other parts of the body. On closing the hand firmly, for instance, cramp occurs and the grip cannot be relaxed.

Hysteria.—In this condition the hand, like other parts of the body, may be involved in a variety of ways, by hyperæsthesias, anæsthesias (often dissociated), slight wasting, vascular phenomena (as flushing, pallor, coldness, ordinary œdema, cyanotic or "blue" œdema), paralyses, sudden temporary loss of power in the muscles, tremor (simple or intentional), contractures, etc. Hysterical contractures of the hand may be temporary or persistent, and usually involve the flexor muscles,

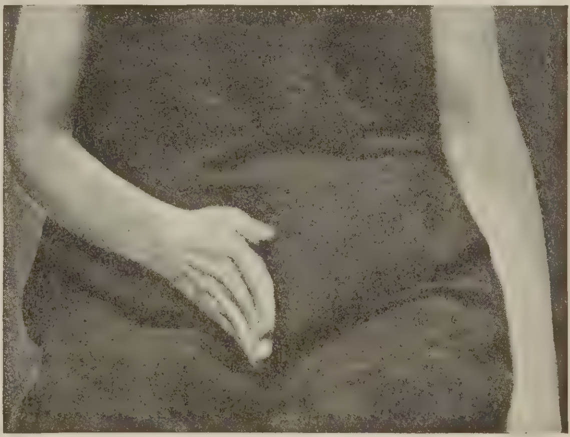

FIG. 2519.—Hysterical Contracture of Extensor Muscles of Hand, of Six Months' Duration. (Dana.)

though sometimes the extensors are affected (Fig. 2519); sometimes the contractures are extreme and very firmly fixed, not yielding to sleep or a mild degree of general anæsthesia; they may continue for months, and cause permanent damage by setting up secondary joint changes.

In *epilepsy* the hand may take part in the spasms. In *chorea* the fingers and hand usually participate actively in the irregular movements and inco-ordination. In the *tics* and *habit chorea* the hand may be involved, though the face is the commonest seat of these disorders.

Paralysis agitans is usually manifested in the hand in a very characteristic fashion. In typical cases the fingers are flexed at the metacarpophalangeal joints and the pulp of the thumb is opposed to that of the index finger; by the constant tremor the opposed thumb and index finger are kept continually rolling over each other, producing the movement described as "pill-rolling." The tremor is usually less during voluntary movements. Muscular rigidity of the digits and hand is often present.

Athetosis, or post-hemiplegic chorea, is a peculiar motor affection of the fingers and toes that occurs most frequently as a sequela of infantile hemiplegia and infantile palsies, less frequently after hemiplegia in adults. It is manifested by slow and deliberate forcible involuntary movements of the digits, in extension, flexion, abduction, and adduction, which take place successively and incessantly, even during sleep. The movements may be complicated and peculiar, and may lead to distorted positions of the hand; they can be only partially and for a short time controlled by the will, and the fingers cannot be permanently kept in any fixed position.

The *treatment* of nervous affections of the hand is in general that of the cause or of the general condition producing the local trouble, together with measures to improve the local condition when no general amelioration is possible.

In wounds in which nerves leading to the hand are divided, the ends of the severed nerve should be carefully sutured together with catgut. If this is not done at the time of the injury, secondary suture, even after months or years, may restore the function of the nerve. If a portion of a nerve is destroyed and the ends cannot be approximated by stretching, plastic procedures or transplantation may be tried.

Developing or impending paralysis and atrophy of muscles and the resulting contractures and deformity may sometimes be arrested, retarded, or diminished by the use of electricity, massage, exercise, passive movements, etc. When deformity is fully developed there is usually little possibility of accomplishing any material improvement, though sometimes the local condition can be somewhat bettered. Thus, division or lengthening of the tendons of contractured muscles sometimes improves deformity and motion. In some cases shortening of the tendons of partially paralyzed muscles, as the extensors, may improve their action. Tendon transplantation, that is, the transference and joining of tendons of non-paralyzed muscles to those of paralyzed muscles, has been tried in the hand in a few cases, in some with good results; thus, in extensor paralysis, some of the tendons of flexor muscles may be cut off and the tendons passed subcutaneously or through the interosseous space to the dorsum of the wrist, where they are sutured to the tendons of the paralyzed extensor muscles. In some cases the use of mechanical apparatus is beneficial. Local trophic changes of inflammatory or necrotic character demand appropriate treatment.

SENILE CHANGES IN THE HAND.

In old age the skin and subcutaneous tissues often become atrophied and thinned, diminishing the size of the hand and fingers. Joint changes are often present, and have been referred to above; they comprise chiefly enlargements (relative or absolute), ulnar deflections, changes in the thumb joint, and other lesions which merge into conditions of rheumatoid character.

Occasionally general palmar induration (as already described) is observed. Trophic changes in the nails—longitudinal ridges ("reedy nail")—sometimes occur. Senile warts (verruca senilis) may develop on the hands as elsewhere; they may be flattish or elevated, pigmented or non-pigmented, sometimes fatty. The back of the hand is a favorite seat for keratosis senilis, which is manifested by warty projections in the form of small papules or larger flattish plates, greasy plates or patches, branny scales, pigmented spots, or in some cases thickening of the entire skin; sometimes the skin of the back of the hand is converted into a dense horny plate. This condition may run into epithelioma. Tremor of the hand, merging into paralysis agitans, is a common senile condition.

CONDITION OF THE HAND IN GENERAL DISEASES.

The changes exhibited by the hand in a large number of general diseases have been already detailed, so that there is little to be added on this subject. In anæmic conditions the hand is pale, cold, dry, and the nails are pale. In conditions of vascular relaxation and atony, weak circulation, or lowered blood pressure, the skin is clammy, cold, purplish, or mottled. In cardiac disease the hands may be congested, cold, clammy, or œdematous, and the fingers may be clubbed. In nephritis the hand is dry, pale, œdematous. In tuberculosis the hand may be emaciated, hot, dry, or sometimes clammy, and the fingers are occasionally clubbed or blunt. Clubbed fingers may occur in other forms of pulmonary disease. The hand is dry and shrivelled in diabetes. Onychias may follow severe acute diseases. In typhoid fever the palms of the hands (and soles of the feet) are usually dry, parchment-like, of a yellow to brownish color, and during convalescence are the seat of active desquamation. In certain forms of idiocy the skin of the hands is loose, wrinkled like a washerwoman's, and looking too large for the hand, while the finger tips are tapering and conical.

John Benjamin Nichols.

HARBIN HOT SULPHUR SPRINGS.—Lake County, California.

POST-OFFICE.—Harbin Springs. Hotel.

ACCESS.—Take boat at Oakland Ferry from San Francisco. At Vallejo change for Napa Valley branch to Calistoga; thence a twenty-mile stage ride brings one to the springs. Time from San Francisco: seven and one-half hours. The location is at the base of a spur of the Coast Range of mountains, 2,000 feet above tide water. Lake County has been justly named the Switzerland of America, and it would be difficult to find a more delightful and picturesque location than that of the Harbin Springs. The mountain air is very invigorating and not subject to extremes of heat or cold, the mean temperature being 70° F. The waters are sulphurous and saline, the principal spring flowing 1,500 gallons per hour. There is also a small chalybeate fount yielding only sixty gallons per hour. The sulphur spring has a temperature of 122° F., and is used for bathing, for which excellent facilities have been provided. Following is an analysis of this water:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	23.05
Sodium carbonate.	5.42
Sodium sulphate	10.19
Potassium carbonate	1.74
Magnesium carbonate	6.18
Magnesium sulphate	11.94
Calcium carbonate	9.10
Calcium sulphate	14.63
Ferrous sulphate	1.75
Arsenious salts	.07
Alumina	1.60
Silica	2.76
Organic matter	Trace.
Total	88.43
Gases.	**Cu. in.**
Carbonic acid gas	4.26
Free sulphureted hydrogen	11.74

It is said that much benefit accrues from the use of this water in chronic rheumatism and gout and other articular affections, as well as in certain varieties of skin diseases.

The chalybeate spring shows the following mineral ingredients:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	7.50
Sodium carbonate	14.22
Sodium bicarbonate	1.45
Sodium sulphate	5.25
Potassium chloride	Trace.
Potassium carbonate	1.73
Magnesium carbonate	4.16
Magnesium sulphate	6.11
Calcium carbonate	2.07
Calcium sulphate	Trace.
Ferrous carbonate	1.90
Alumina	.73
Silica	1.41
Organic matter	Trace.
Total	46.53

Carbonic acid gas, 9.34 cubic inches.

This water is clear and sparkling, and has a pleasant taste. It is tonic, antacid, diuretic, and aperient, and is useful in dyspepsia, anæmia, chlorosis, chronic malarial poisoning, and wasting diseases. In addition, there are two more springs of some importance; they are known as the "Magnesia" and the "Arsenic" springs. The last-named spring has gained quite a reputation in syphilitic and skin diseases, glandular indurations, etc.

James K. Crook.

HARDHACK. (See *Rosaceæ.*)

HARELIP, unlike cleft palate, may be regarded as a strictly congenital malformation. It is a deformity that, from its peculiar prominence, has brought more sorrow to the hearts of parents than perhaps any other of nature's defects. To the surgeon it has been the source of more thought and care as regards the operation for its relief than are demanded by many surgical problems of far greater importance.

Like cleft palate, it may be looked upon as an arrest in fœtal development, confined, with very rare exceptions, to the upper lip. When situated in the lower lip, there are many deformities that may coexist with it, such as combined fissure of the lower jaw and tongue, and a variety of other like complications. Sir William Fergusson, in the fifth edition of his "Surgery," p. 506, speaks of several cases of this kind which had been observed by himself and others in their practice.

Associated with upper harelip are sometimes remarkable deformities about the face; for instance, the fissure may extend up along the nose on one or both sides to, or into, the eyelids, or it may extend out on one or both sides from the angle of the mouth, and may implicate Stenson's duct, a very unpleasant complication.

Mason speaks of a cyanotic condition of the child. This condition, which I have also observed, is, at times, cured by the operation for closure of the fissure. Mr. George Lawson gives the explanation (*Lancet*, June 7th, 1862, p. 599) that during the lull in the circulation, in cases in which faintness occurs, the foramen ovale becomes closed and thus the double current is established.

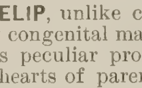

FIG. 2520.

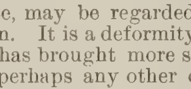

FIG. 2521.

The pathology of harelip is a subject into which the narrow limits of an article like the present one will not permit me to enter except in the most superficial manner. M. Coste[1] states that the mouth is formed between the twenty-fifth and the twenty-eighth day of fœtal life. The frontal lobe becomes much enlarged, and shows a great hollow which divides into two smaller lobes, called by him the incisive centres, and from which the incisive bones and the middle portion of the upper lip are developed. The centres for the superior maxillæ, which form the lateral parts of the upper lip, converge one toward the other, and come nearer to each side of the corresponding incisive centre. At the fortieth day the two incisive centres, in the substance of which the incisive teeth are developed, unite one to the other in the middle line and thus complete the central portion of the upper lip. Thus, if the two lateral portions do not unite with the incisive portions, we have a double, or bilateral, harelip; if only one of these sides fails to unite, then we have a single, or unilateral, harelip.

FIG. 2522.

I have, in a few of my earlier operations, removed the intermaxillary bone, and, on examination of it, have noted an absence of the lateral incisors. This, I believe, has been the experience of most surgeons who have given careful thought to the question whether this island contained all of the upper incisors or not. In two cases that I examined a few years after the operation for cleft palate, in which I had saved the intermaxillary bones, I found in each instance an irregular lateral incisor on the right side, back of the regular row of teeth.

Fergusson, Demarquay, Gurdon Buck, and others report a large number of cases which illustrate the fact that harelip appears in some families through many generations, and I have observed this in the record of my own cases. Like webbed fingers and toes, harelip is often seen without any evidence of consanguinity being present.

There are few surgeons, I suspect, who have examined cases of harelip carefully, who have not been impressed with the effort so often made by mother or nurse to prove that the deformity is entirely due to some fright which the mother has experienced and which in her estimation has produced its effect upon the child in utero. Maternal impressions may be one of the factors in the production of harelip, and yet evidence of such cause is so often wanting as to lead us to doubt.

Acting early upon the suggestion of the late Sir Wm. Fergusson, I have examined many lips and jaws for fissure, and have frequently found slight notching or partial defects on the mouths of one or the other of the parents.

I have frequently had occasion to call the attention of my class to this point in the study of these cases. This is very well shown in Figs. 2520 and 2521, from Mason.* Some cases are not so well defined, the amount of depression in the vermilion border of the lip being much less. I have noticed that close pregnancies form a factor in causing this deformity. In connection with these cases it is not unusual to see in the same patient extra thumbs or fingers, spina bifida, and the like. The late Professor Alden March had a child brought to his clinic, for relief of harelip, who had cleft palate, an extra toe and finger upon each foot and hand, double hernia, and club foot. He thought the child hardly in a proper condition for operation, and quietly said to the poor mother, "My good woman, you had better try it over again."

Accidents, bites of dogs and other animals, treatment of nævi, and other surgical conditions may result in a temporary form of harelip, which may be said to be cured generally in the final treatment given to such lesions. In the case of Miss C——, aged six, suffering from nævus on the upper lip, whom I had treated in various ways without complete success, the final injection of a solution of tincture of iron produced a slough resulting in a fissure such as is seen in Fig. 2522, but which was closed with scarcely any scar by means of two silver harelip pins.

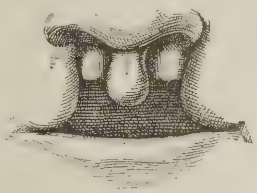
FIG. 2523.

A considerable number of cases is met with in which the kind of harelip is of the double variety, as seen in Fig. 2523, from Mason. In this variety the fissure may be very slight on one side and yet complete on the other, or, in cases in which there is a double fissure of the alveolar arch, as in cleft palate, we may have the horrid horn-like projection as seen in Fig. 2524, from Mason, and in one of my own cases, Fig. 1363, of vol. III.

Cases of median harelip have been recorded by surgeons, but they are exceedingly rare, and their existence has even been doubted by some. In the autumn of 1883 there was brought to my clinic a female child (two and one half years of age) in whom a cystic tumor at the tip of the nose was complicated by a complete median fissure of the upper lip. Fig. 2525 (from a sketch of the little patient) shows the case very well. Sir Wm. Fergusson has very justly remarked that, after the operation has been completed, one cannot judge correctly as to whether the case was originally one of a median fissure or of double harelip, for many cases of the latter defect, when operated on, show a decided tendency to the formation of a cicatrix in the middle line. Fig. 2526, one of my own cases, and quite as bad a case of double harelip as I have ever operated upon, shows this condition clearly. It is a singular fact that in these various kinds of fissure in the upper lip there is really very little loss of substance. One finds this to be true by merely approximating the soft parts temporarily.

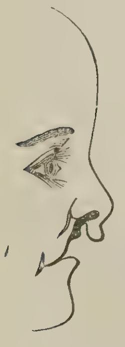
FIG. 2524.

Regarding the period of life when it is best to operate, in cases of harelip, much has been said by the older operators, but with little unanimity of opinion; some advising interference in infancy, others preferring to wait until advanced childhood. At the present time, I am of the opinion that modern surgeons prefer the early operation. My own experience teaches that a good time for the operation is when the infant is about six weeks old, especially if the child be healthy. In a case of double fissure perhaps it is well to wait until the child is six or seven months old. Of one thing I am certain, that in the latter complication we should perform the operation as early as possible, in order to secure the good effect which is produced upon the soft parts when the cleft in the hard palate is obliterated by operative interference,—an effect which, in a period of two years, amounts to a great deal.

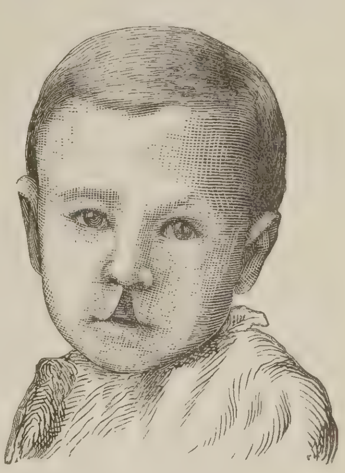
FIG. 2525.

In cases of double harelip I prefer to operate on one side at a time and to save all that is possible of the island or intermaxillary bone. In operating upon one side at a time, the first should be allowed to become firmly healed before we resort to the second operation. Ordinarily, this interval would amount to at least two months. I sometimes in these cases give to the skin covering the island the form of a square, and then, making flaps from the upper lip and cheeks on each side, secure a good, full lip, one which does not appear at all constricted. I am convinced that in doing the operation we should pare the edges of the fissure freely, but not throw the pieces away—that is, not finally detach them; therefore, I believe that the operation which embodies this principle is the best.

Operations upon the adult are exceedingly rare, and and are then generally performed for the purpose of improving an imperfect result following an early operation. In a few instances I have been obliged, for such a reason, to operate on an adult.

In operating for harelip we should in all cases be sure to loosen well the attachment of the cheek to the alveolar process; there should be perfect freedom of movement, and no restraint put upon the parts when the pins or sutures—whichever may be selected—have been introduced. This is generally best done with a long, blunt-pointed tenotome.

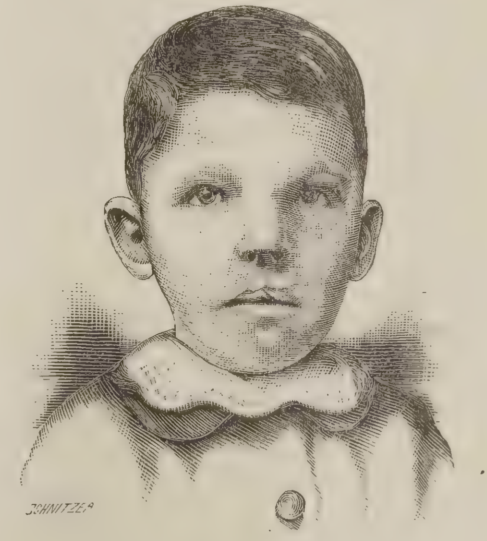

FIG. 2526.

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* Mason: "On Harelip and Cleft Palate."

The position of the infant at the time of operating is a point of much importance. If the child is strong, I believe it safe and wise to give chloroform, or whatever anæsthetic the surgeon considers to be the best.

Having the child held by a good nurse or competent assistant—as is spoken of by so many writers—is often the easiest and best for the operator; but I am much in favor of placing the little one on a narrow, firm table of proper height, around which the assistants can work more at ease and not be in the way of each other. Standing on the right side of the table and patient, the operator proceeds to free or loosen the fissure on each side, as I have already stated. After this has been thoroughly done, he directs an assistant, opposite to him and at the head of the child, to grasp the left side of the fissure between the forefinger and thumb of his left hand, and then, with his right forefinger and thumb, to hold the right side in the same manner. The surgeon may now, with the so-called harelip forceps, or simple forceps, grasp one edge of the fissure, and, introducing a sharp-pointed narrow knife at the point of the cleft nearest the nose, carry the knife from above downward toward the vermilion border of the lip. He should then repeat the same steps on the other side, in each instance removing sufficient tissue to give good, broad surfaces for mutual contact. In a simple harelip I often pare the edges of the fissure with a strong pair of curved scissors (Fig. 1382, vol. III.). Thus far, if the assistant's thumbs and fingers are not too large, and if he performs his part well, but little blood will have been lost. I consider the compressors of the upper lip for controlling hemorrhage, spoken of by some authors, as really not necessary, but if they are to be employed I would recommend an instrument like that shown in Fig. 2527 (copied from Mason).

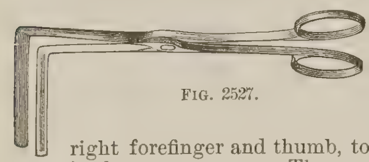
Fig. 2527.

The next step in the operation involves the closure of the fissure. It must ever be borne in mind that the vermilion border of the lip should be well preserved, with no sliding upward or downward on either side, and also that there ought not to be any notching.

As to the kind of suture that should be employed, I must say that my preference is for the silver harelip pins. In introducing them, I prefer that the first should be inserted nearest the vermilion border; it should be passed from the left to the right side of the fissure, and the greatest care should be exercised to bring the parts into good apposition. Of course, these steps may be modified or reversed if there is a single right-sided fissure, or if the surgeon stands in front of the child. Fig. 2528 (from Mason) illustrates my point. The pin should be introduced at least a quarter of an inch back from the freshened edge of the fissure, and it should pass obliquely through the edge of the lip, but should not include the mucous membrane; it should then enter the opposite side and emerge in the same manner. Now, around this pin put a figure-of-eight silk ligature, not too tight, as some allowance must be made for swelling. Then, next above this first pin, introduce in a similar manner one or two more, as may be needed. If two are used, it is well to bring them together by one ligature, crossing from one pin to the other, as by adopting this plan one is not likely to get so much of a slough—that and ulceration being the two great dangers associated with the employment of silver pins.

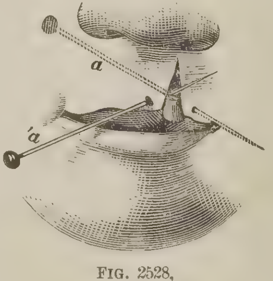

Fig. 2528.

Sometimes it is necessary to introduce between the pins a few fine superficial silk sutures, and also to place two or three in the mucous membrane and one in the vermilion border of the lip, not leaving them in for more than twenty-four or thirty-six hours. In the case of the mucous membrane I prefer to use fine catgut sutures, and I then leave them undisturbed.

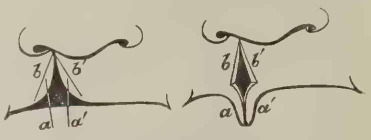

Fig. 2529.—Malgaigne's Operation.

After the pins have been introduced the points should be cut off with bone forceps, and a small portion of absorbent cotton should be put under each end. They are not to be left in longer than three days, as a rule, and should always be watched with care to prevent ulceration or sloughing. It is better to take them out too soon than to leave them in too long.

Some surgeons prefer simple silk, others silver wire; then, besides, many other devices have been suggested. I take it that few surgeons rely upon the rubber or adhesive plaster to hold the parts in apposition while the healing process goes on; but after the pins and sutures have been removed, in order to prevent too much tension on the newly formed tissue, I am in the habit of holding the parts well in apposition by placing narrow strips of plaster across from ear to ear. These hold the cheeks quiet and restrain the movements of the lips. Mr. Mason speaks of the use of collodion over pins and sutures. After the operation the child should be kept quiet by the use of anodynes, if necessary. He should be fed first with a spoon, and, when all is going well, after a few hours, or perhaps one, two, or three days, he should be allowed to nurse or take the bottle. Crying should be prevented as far as possible, and yet it is surprising to note how little harm it does.

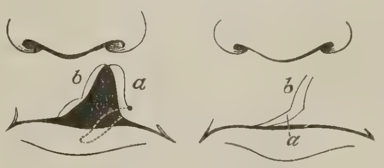

Fig. 2530.—Mirault's Operation.

It is clear that no one special kind of operation can be made to apply to every variety of harelip. Fortunately, we have a choice among numerous modes of procedure which practice has demonstrated to be successful. In the operation known as Malgaigne's, the incision is commenced at the superior part of the lip, and performed from above downward (Fig. 2529, left side, *b*, *b'*). Scissors are used as in ordinary operations, except that, when the operator has reached the lowest point possible without detaching the cut piece, he stops (Fig. 2529, left side, *a*, *a'*). The other side of the labial fissure is treated in the same way. There are then two small flaps each one of which adheres to the lip by a pedicle. After having reunited, by the aid of pins, the two margins of the cleft in their whole extent, except toward their free border (that is, toward the bottom), the surgeon should bring these flaps from above downward and should approximate them face to face (Fig. 2529, right side, *b*, *b'*). The point now is to adjust these flaps (partly by shortening them) in such a manner as to prevent the later development of a furrow. This result, which is so commonly dreaded by surgeons, may be prevented, at this stage of the operation, by preserving a piece varying in size according to the extent of the vacuum to be filled (Fig. 2529, right side, *a*, *a'*). Union is afterward effected by approxiating the parts with one or two interrupted sutures or with a fine harelip pin. If care is taken to place these uniting

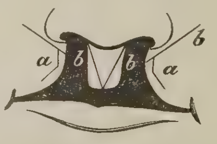

Fig. 2531.—Sédillot's Operation.

agents very near the free margin of the lip, the cicatrices will scarcely be visible.

M. Mirault, of Angers, employed one flap only. A flap is taken from above downward, but is left attached to the prolabium (Fig. 2530, left side, *a*); on the other side of the cleft the margin is completely removed (Fig. 2530, left side, *b*). The flap, *a*, is now turned down, and from being perpendicular, it becomes horizontal, and forms the margin of the lip (Fig. 2530, right side, *a* and *b*).

For double harelip Sédillot suggested a cheiloplastic operation. The sides of the central tubercles being pared, a flap of soft tissue is taken from each side, as shown in Fig. 2531. The flaps, *a*, *a*, are brought down to form the red margin of the lip, and the raw surfaces, *b*, *b*, then come in contact with the raw surfaces on the sides of the central tubercle, *b'*, *b'*.

Dr. A. M. Phelps, of Chateaugay, N. Y., in a paper read before the Medical Society of the State of New York, February, 1885 (see Transactions, p. 255), presented an operation for single harelip which contains some original and striking features.

The steps of the operation are these:

"After first passing a loop through each angle of the lip for the forefinger of the left hand to hold the parts perfectly, with a pair of curved scissors separate the lip from its attachment to the jaw sufficiently to freely relieve the nostril and make all parts easily movable. The mucous membrane should be freely divided in both directions. With an ordinary cataract knife, or a slender, sharp tenotome, puncture the lip at 1 (Fig. 2532), following the dotted lines describing a curve to 2, and from thence to 3. Withdraw the knife after going freely through each nostril at 3, and with a scalpel cut from 3 to 4 through the entire thickness of the lip. The pieces, *B* and *B*, will now turn downward, leaving the **V**-shaped piece as seen in Fig. 2533.

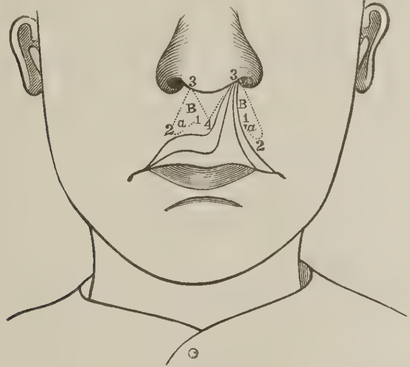

FIG. 2532.

"Now introduce the silk sutures as shown in Fig. 2533, after which cut away the pieces *B* and *B*, and the result will be shown in Fig. 2534. Before cutting away the pieces *B* and *B*, pull the lip up with them and stitch the mucous membrane together with catgut as far underneath as possible. Enough tissue should be left in the median line to compensate for retraction. The temptation is to cut the pieces *B* and *B* too short. It is better to cut them long, and, if necessary, trim them a little.

"The following are a few rules which it is well to observe:

"1. Select only those cases in which one-fourth of the lip, at least, remains between the fissure and the corner of the mouth.

"2. Each curved incision, 1, 2, and 3 (Fig. 2532), should be an equal distance from each corner of the mouth. The curves should be similar, and both should enter the nostril at the same point on each side. On the normal side the incision should enter the nostril near the columna, and but little or none of the nostril be cut away. When the deformed nostril is drawn to a normal position the incisions will then correspond. Fig. 2532 will convey the idea.

"3. The incisions from 3 to 4, making the **V**, should extend to fully one-half the breadth of the lip. If the **V** is made too short, difficulty will be experienced in getting the lip together. This would necessitate a more extensive division of the mucous membrane, or possibly the addition of transverse incisions extending outward into the cheeks under the corners of the nose.

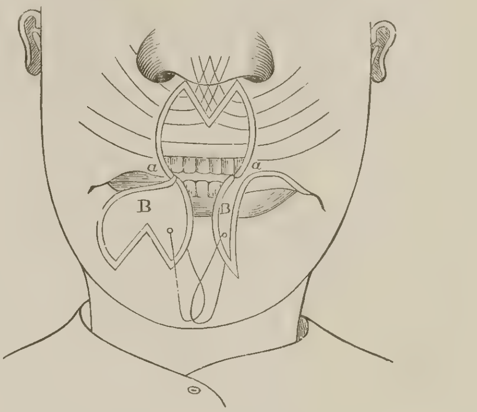

FIG. 2533.

"A fatal mistake would be to get the centre piece too long, as it would make a deformity. Cut it away to just the length to admit of the lip being stitched together, varying it according to the tension in each case, *making it as short as possible.* It would be much better to make the transverse incisions to relieve tension than to leave it too long, should a case not suitable for the operation be selected.

"The steps as followed in single harelip should also be followed in double, using the double curved incisions already described.

"The advantage of the double curved incision is this: When the pieces *B* and *B*, Fig. 2532, are turned downward, the curve at *a*, *a*, becomes straight, and when joined to its fellow of the opposite side, adds just so much to the width of the lip, at a point where it is desired, as the distance is from 1 to 2, Fig. 2532. The widening of the lip at this point, and the curving downward of the white line above the vermilion border of the lip into the point, is what lends the artistic appearance to the lip." An artistic lip and a scar in the median line are the strong points which characterize this operation.

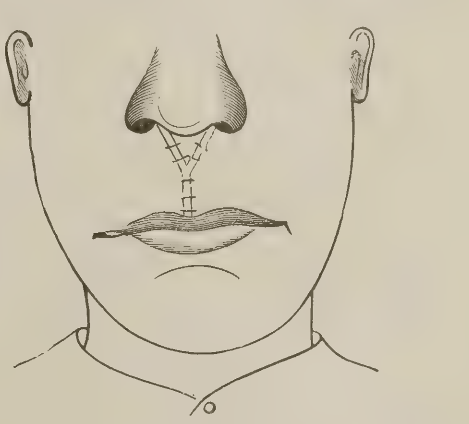

FIG. 2534.

Dr. M. H. Collis,[2] of Dublin, says: "I never throw away a particle of the parings. My incisions are made so as to make every fragment of them useful. On one side they are preserved to make the lip thick, and on the other to increase its depth. The method is somewhat complex, but a reference to the accompanying figures will make it intelligible (Fig. 2535). When dealing with single harelip, I take the larger portion, that which includes the middle bit, and pare it freely from the nostril round the margin from *a* to *b*, until the point of the knife comes opposite the frænum. The incision goes through all the tissues of the lip *except* the mucous membrane. It follows the curved line of the margin of the fissure, and leaves a long wound, which is curved toward the fissure. The flap is left loose and attached only by mucous membrane. On the other or smaller side of the lip, where we generally find the tissues thin, especially as we approach the nostril, the treatment is quite different. I transfix the lip at *d*, close to the nostril, and carrying the knife along parallel to the margin as far as *f*, I detach a moderately broad flap, which I leave adherent above to the ala nasi, and below to the free margin of the lip, well beyond or external to the rounded angle at the fissure. This flap, which (unlike the one at the opposite side) comprises *all* the tissues of the lip, is now divided into two at its centre (*c*, *e*). I thus get two loose flaps, a superior (*c*, *d*), attached to the ala nasi, and an inferior (*e*, *f*), hanging on to the free margin of the lip. The loose end of the upper flap is turned up so that its raw surface faces the wound in the opposite side of the fissure, and the lower end of the lower flap is similarly turned down. The point *c* is brought up to *a*, and fastened there. The point *e* is brought down to *b*, and fastened there. I have thus got on the small side of the lip a wound as extensive as that on the larger side. The upper flap completes the outline of the nostril. The lower one supplements the outline of the free margin of the lip. I thus get a lip nearly double in depth any which I could possibly have got by the ordinary incisions."

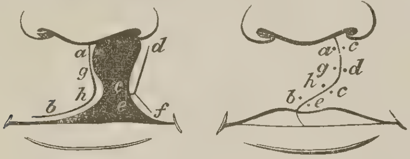

FIG. 2535.—Collis' Operation.

Mr. Thomas Smith recommends an operation which is useful in suitable cases of double harelip. According to his plan the lateral sides are to be pared in the manner shown in Fig. 2536, *a′ a*, and two flaps are to be taken from the central tubercle, but are not to be detached at their lower margins. "The wound is closed by drawing down the flaps from the side of the central tubercle, and attaching them to the raw surface on the lower margin of the lip."

The condition of the infant before operating should be as good as possible. There should be no unfortunate surroundings, especially as regards diphtheria and allied conditions, nor should the operation be done in hot weather, or at any time in the year when epidemics of any kind peculiar to children are prevailing.

As a general rule, one operation is all that is needed, but sometimes failure occurs, and in this we ought not to be discouraged, but, as soon as the child has sufficiently improved, we should try again.

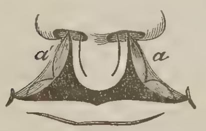

FIG. 2536.—T. Smith's Operation.

Regarding Hainsby's truss, I have had but little experience in its use, and must say that it requires great care, and is apt to annoy the child.

As to a second operation, years after the first, to relieve an unsightly scar or depression in the vermilion border of the lip, I am much in favor of its performance, especially in females.

Albert Vander Veer.

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[1] Mason.

[2] *Ibid.*

HARRIS LITHIA SPRINGS.—Laurens County, South Carolina.

POST-OFFICE.—Harris Springs. Hotel and Cottages.

ACCESS.—Viâ Georgia, Carolina, and Northern Railroad (Seaboard Air Line) to Cross Hill; thence two and one-half miles to springs. Or, viâ Port Royal and Western Carolina Railroad to Waterloo, and thence two miles to springs. These springs are located in a hilly country, and are open for the reception of visitors during June, July, August, and September. They are two in number, known respectively as the "Lithia" and the "Sulphur" Springs. They flow about sixty gallons per hour each. The following analysis was made by Prof. R. Ogden Doremus, of New York, in 1891:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Calcium sulphate	83.38
Potassium sulphate	.51
Sodium sulphate	.58
Sodium chloride	.76
Sodium bicarbonate	2.42
Lithium bicarbonate	2.32
Magnesium bicarbonate	3.04
Iron bicarbonate	.32
Silica	2.51
Phosphoric acid	Trace.
Loss on ignition	15.84
Total.	111.68
Total dried residue at 266° F.	98.57
Carbonic acid in bicarbonates	3.35
Total solids per United States gallon	101.92

The combination of mineral ingredients shown in this analysis would suggest a very useful water. It is highly effervescent and agreeable to the taste. It is therefore useful for the table, and mixes well with wines. It is a speedy corrector of acidity to the stomach. It is said that the water causes a notable reduction of sugar in the urine in diabetes mellitus. It also overcomes constipation, and is useful in rheumatism, uric-acid gravel, calculi, etc. The water has an extensive sale.

James K. Crook.

HARRISON HOT SPRINGS.

LOCATION.—British Columbia.

POST-OFFICE.—Harrison Hot Springs. Hotels: St. Alice and Bath.

ACCESS.—By Canadian Pacific Railway to Agassiz, thence by stage.

ANALYSIS FROM THE LABORATORY OF THE GEOLOGICAL SURVEY OF CANADA.

	Sulphur Spring.	Potash Spring.
Temperature of spring	150° F.	120° F.
Specific gravity, 60° F.	1001.13	1001.10
Chloride of potassium	1.722	1.414
Chloride of sodium	31.297	28.413
Chloride of lithium	Trace.	Trace.
Sulphate of soda	33.061	28.749
Sulphate of magnesia	.147	.168
Sulphate of lime	14.000	15.792
Sulphate of strontia	Trace.	Trace.
Bicarbonate of lime	6.259	3.689
Bicarbonate of iron	4.634	4.102
Alumina	Trace.	Trace.
Silica	Trace.	Trace.
Organic matter	......	Trace.
Grains, per imperial gallon, at 60° F	91.960	82.327

These springs are situated on the western slope of the Rocky Mountains, sixty miles from Vancouver. The hotels are excellent and provide every comfort for the tourist or invalid. The baths are well arranged and a doctor and skilled attendants reside at the sanitarium. The climate is mild during the entire year, the thermometer seldom going below the freezing point, and the variations are never extreme. The hotel is situated on Harrison Lake and is surrounded by snow-capped mountains. The scenery is beautiful and the finest fishing and shooting are to be obtained in the neighborhood.

Beaumont Small.

HASTINGS AND ST. LEONARD'S, ENGLAND.—These two places, virtually one town of about 50,000 inhabitants, are situated sixty-two miles southeast of London on the coast. Their claim as a health resort is based upon the mildness of their winter climate, which renders them a comparatively favorable residence for those of feeble vitality, and for sufferers from chronic bronchitis or other form of "mucous membrane delicacy."

The front of the town looks toward the South and the open sea, and an esplanade three miles in length extends along the shore. In the rear are downs which afford shelter from the northerly winds. The country about is picturesque, affording many attractive excursions; there are also various public parks and gardens. Roundabout are hills broken by numerous valleys, thus offering some variety of climate. The soil is more or less sandy, through which the rain water rapidly escapes.

The mean average temperature for the four seasons is as follows: Spring, 45.9° F.; summer, 59.9° F.; autumn, 51.5° F.; winter, 39.9° F.; for year, 49.9° F.

The mean daily range is 10.4°.

The day temperature averages 54.6° F., and the night temperature 44.2° F. The mean relative humidity is 84 per cent. for the year.

The most prevalent winds are from the west and southwest. The average rainfall is 29.95 inches per annum, falling on an average of one hundred and eighty-three days.

The mean amount of bright sunshine (average for eight years) is 1,699.9 hours, or 4.6 hours per day; the least amount is during the winter months.

Sea fogs are not infrequent but do not last long; land fogs are rare. The sea front enjoys the mildest winter climate, on account of its southerly exposure and shelter from the northerly winds; it is therefore the place of residence for the invalid, in winter. The mildness of the winter climate is indicated by the various plants and shrubs which flourish during that season, such as the arbutus, primrose, hepatica, violet, and hydrangea. The drainage is good, and the water supply abundant and of good quality. Along the esplanade before mentioned are hotels, lodging houses, private residences, and shops. In the spring the east winds begin to blow, and these are often "searching," but are somewhat mitigated by the bright sunshine.

Mildness and equability, with protection from northerly winds and a comparatively large amount of sunshine, are the characteristics of this climate from which these towns have derived their popularity as a winter health resort.

The southwest wind which is the prevalent one, except in the spring, is said to render the climate somewhat relaxing.

Patients affected with various maladies frequent this resort; phthisis, chronic bronchitis, convalescence from acute renal diseases, scrofula and anæmia are the principal diseases which are benefited by this climate. Very many phthisical patients are reported as doing well under its influence.

"The long, sunny parade, sheltered from northerly winds, offers facilities for outdoor exercise. Many persons have found that they can pass the winter at least as well here as in Southern Continental health resorts. This is especially the case when the patients can be induced to admit fresh air into their rooms freely both day and night. The 'fresh-air cure' is more practicable in a South of England seaside resort than inland, where the night air is damper and more chilly." ("Climates and Baths of Great Britain," 1895.)

"The contraindications, beyond those which apply to marine stations in general, are singularly few."

Edward O. Otis.

HAWAII.—The Territory of Hawaii, United States of America, consists of twenty islands in the mid-Pacific ocean between north latitudes 18° and 30°, and west (Greenwich) longitudes 154° and 172°. The islands comprising this territory are: Hawaii, Maui, Oahu, Kauai, Molokai, Lanai, Kahoolawe, Niihau, Molokini, Lehua, Kaula, Bird, Necker, Johnson, Laysan, Lysiauski, Ocean, Midway, French Frigate Shoal, and Pearl Reef. The eight first-named islands are inhabited permanently, and constitute the ones usually comprehended as the Hawaiian or Sandwich group. (Three of the eight, Niihau, Lanai, and Kahoolawe, are, however, nothing more than cattle ranches.) The remaining twelve are small islets, little more than rocks or coral reefs, and uninhabited except at such times as they are visited by workmen of guano companies collecting the eggs and the manure of the innumerable sea birds and turtles making these spots their homes. The areas of the eight major islands are:

	Square miles.		Square miles.
Hawaii	4,015	Molokai	310
Maui	760	Lanai	160
Oahu	600	Niihau	97
Kauai	590	Kahoolawe	69

Honolulu, the capital of the Territory, in Oahu is 2,100 miles from San Francisco, 3,810 miles from Auckland, 3,440 miles from Yokohoma, 2,380 miles from Tahiti, and about 4,000 miles from Manila.

History.—The islands were visited by some Spanish navigators as early as 1542, and two Spanish ships were wrecked on them probably in 1527. The actual, that is, useful, discovery of the islands was made by Captain Cook in 1778, who gave them the name of Sandwich in honor of the first lord of the British Admiralty at the time. Hawaii, the native name of the largest member of the group, has, however, been the one generally applied to the archipelago, and is now the legal name of the Territory. At the time of Cook's discovery the different islands were governed by one or more independent chiefs. Shortly thereafter Kamehameha, a chief of Hawaii, subjugated the other chiefs, and established the kingdom of Hawaii, which remained with some vicissitudes an independent government till 1893. Liliuokalani, who succeeded her brother King Kalakua, in 1891, having manifested an intention to change the existing constitution, provoked a revolution, January, 1893, in which she was deposed. A provisional republic was proclaimed and negotiations were begun looking to the final annexation of the islands to the United States. A republic was formed in 1894, and negotiations continued. After some delay, caused by changes in the political ascendencies in the United States, the islands were finally admitted into the Union as the Territory of Hawaii. The annexation took place formally August 12th, 1898.

Population.—Captain Cook estimated the native population as 400,000 inhabitants, an estimate undoubtedly too great. The first census, taken in 1823, showed 130,313 natives. According to the census of 1878 these had decreased to 44,088. A census of the islands in 1896 gave a total population of 109,020 inhabitants, composed as follows:

Native Hawaiians	31,019	Americans	3,086
Mixed Hawaiians	8,485	English	2,250
Japanese	24,407	Germans	1,534
Chinese	21,616	Other nationalities	1,420
Portuguese	15,191		

The present outlook is the gradual extinction of the native Hawaiian race. The decrease in native population gave great concern to the original government and strenuous efforts were made to check it, but without avail. In general appearance the natives are fine specimens of physical development; the women, however, are not fruitful, and few families are found with as many as three children. The original islanders belong to the widely scattered Malayo-Polynesian family. Although more than 3,000 miles of ocean intervene, Hawaiians and the Maoris of New Zealand can readily understand each other's speech. Cannibalism, idolatry, and human sacrifices were practised at the time of discovery, though the cannibalism was only moderate, and to some extent a part of the religion. The religious adhesions of the present population are almost as diverse as the races are polyglot. The census of 1896 gave Roman Catholics 26,363, Protestants 23,773, Mormons 4,886, Buddhists, Confucians, and other Oriental sects 44,306, unknown 10,192. Notwithstanding the recent influx of foreigners due to political changes, the condition of population offers material for serious consideration. Agriculture is the industry of the islands, and laborers are imperatively needed in agriculture. The larger part of the arable land of the archipelago is devoted to sugar production and the conditions under which this industry is practised at present discourage a peasant proprietorship of the land. Without such proprietorship there can be little hope of a permanent population. There are at present a total of about one hundred miles of railroad in operation. Most of the important points on the larger islands are connected by telephone or telegraph. Oahu and Hawaii are connected by submarine cable, and it is not improbable that by the time this article is in print a cable will be in construction to join San Francisco and Honolulu. The valuation in 1900 of the imports into the United States was $20,707,903, and of the exports from the United States to the islands, $13,509,148. The facilities and conveniences of living in Honolulu and Hilo, the chief towns, are the same as those in like cities of the United States. The cost of living is, since annexation, however, higher, largely due to the servant question. The Chinese constitute the chief source from which this element is drawn, and since annexation they are excluded from the islands as from all other parts of the Union.

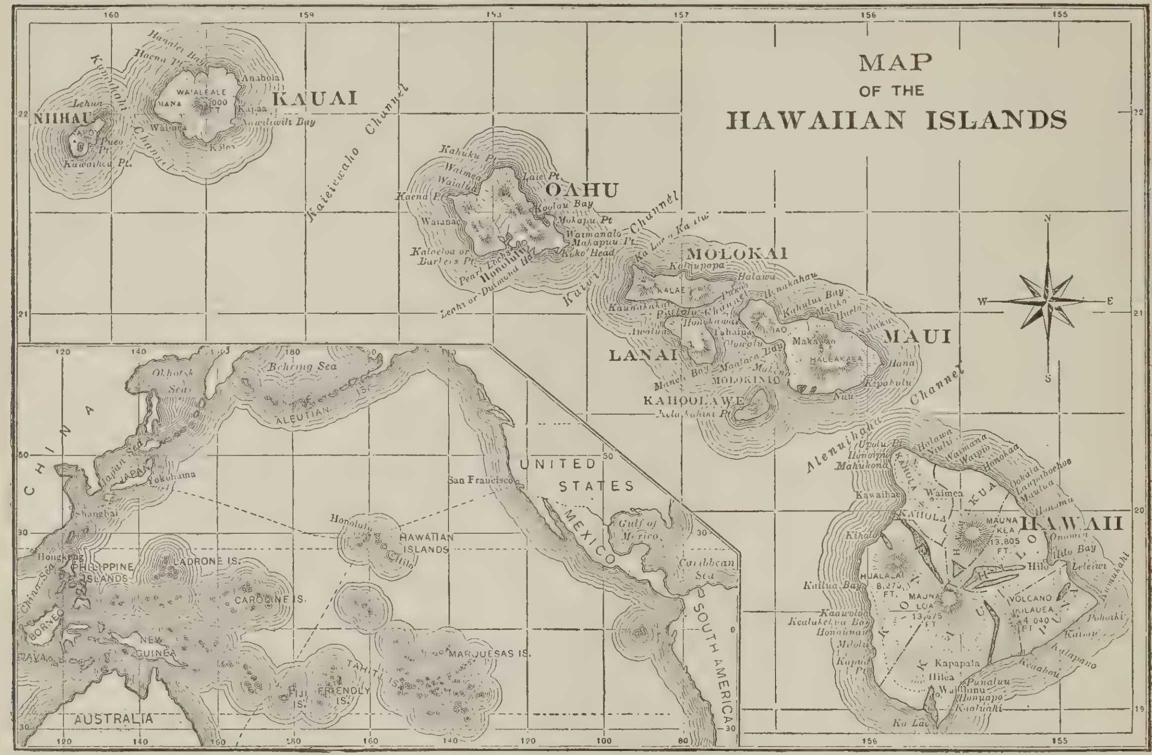

FIG. 2537.

Geography and Geology.—The Hawaiian Islands are of volcanic origin. They rise from the general level of the ocean bottom to the surface a distance of 14,000 to 19,000 feet. This rise is so abrupt that this great depth of water is found from 30 to 50 miles from shore. Above sea level the islands attain elevations that in many places rival the heights of the Alps. The coast line is in places low, in others it rises often sheer 2,000 feet. The following tabular view shows the chief elevations.

Islands.	Name of mountain peak.	Height above sea, feet.
Hawaii	Mauna Kea	13,805
Hawaii	Mauna Loa	13,675
Hawaii	Hualalai	8,275
Hawaii	Kilauea	4,040
Hawaii	Kohala mountains	5,000
Maui	Haleakala	10,032
Maui	Eeka	5,820
Kahoolawe	(Highest point)	1,130
Lanai	(Highest point)	3,000
Molokai	(Highest point)	3,500
Oahu	Kaula	4,060
Kauai	Waialeale	5,000

Geologically, Hawaii is the most recent and Kauai the eldest of the group; the islands increasing in age from the southeast to the northwest. Kauai from its greater age has the best weathered soil, and by its inhabitants is proudly called the garden island. The soil of the islands is weathered lava. It is extremely porous. Two general classes are recognized, dark red soil, from simple weathering, and light red and yellow soils from weathering plus the action of imprisoned sulphurous and other gases. The dark red is the better and more durable agricultural soil. The light red and yellow soils require careful cultivation. But few minerals are found. Sulphur, pyrites, copperas, sal ammoniac, common salt, and a few others are the chief ones. Hawaii has the only active volcano, the world-renowned crater Kilauea. The summit of Mauna Loa has a crater, Mokuaweoweo, occasionally active. From Hilo, the chief town of the island, a good road, thirty miles in extent, runs to Kilauea. Haleakala, in Maui, is an extinct crater, the largest known in the world. Although more than 10,000 feet high, so gentle is the slope that it can be ascended to the top on horseback. Most of the other mountains of the islands are more or less easily rising slopes, and mountaineering is not arduous.

Flora and fauna. The mere enumeration of the varieties of flora on the islands would exceed the length of this article. Hillebrand, in his "Flora of the Hawaiian Islands," names 999 species and 365 genera, and many others have been introduced since his book was published. "The variation in the climatic conditions due to altitude and location . . . together with the arable soil at all altitudes, justify the belief and warrant the assertion that almost every tropical and temperate plant can somewhere be grown successfully on this island" [Hawaii] (Dr. W. C. Stubbs, "Report on the Agricultural Resources, etc, Hawaii," Washington, 1901). Over seventy species of birds, mostly water fowls, have been enumerated. Captain Cook found hogs, dogs, domestic hens, and rats, on the island, also a day-flying bat. Cattle, goats, and hogs, escaped from domestication, run wild (goats were introduced by Vancouver in 1792) and have damaged the forests incalculably.

Climate.—The Hawaiian Islands are climatically within the sea level isotherms of 70° and 75° F. The average sea-level temperature of the group is 4° to 6° lower than the calculated average of the latitude (see table, article *Climate*). The distinguishing characteristic of Hawaiian climate, compared with that of other tropic islands, is the combination, in its temperature, of mildness and equability. There are many other tropic islands that have great or even greater equability of temperature, but they lack in greater or less degree the other element of mildness so pronounced in the perpetual, pleasant summer of the Hawaiian archipelago. The following table shows the temperature of Honolulu compared with that of some other insular localities in or near the tropics.

	AVERAGE TEMPERATURE OF—		
	Year.	Warmest month.	Coldest month.
Honolulu	74° F.	78° F.	70° F.
Praia, Cape Verde Islands	76	80	72
Las Palmas, Canary Islands	70	75	65
Bermuda	70	80	63
Nassau, W. I	77	82	72
San Juan, Porto Rico	81	84	76
Saint Helena	71	76	68
Mauritius	74	79	69
Tahiti	77	80	74
Levuka, Fiji Islands	78	82	75
Réunion	74	79	70

The average temperature and rainfall at Honolulu are:

	Temperature.	Rainfall (inches).
January	70	3.5
February	71	6.0
March	71	3.3
April	73	3.0
May	74	3.0
June	76	1.6
July	77	1.8
August	78	2.0
September	78	2.0
October	76	2.5
November	74	5.5
December	72	4.7
Year	74	38.4

The temperature seldom, if ever, rises to 90° F. According to C. J. Lyons, the territorial meteorologist, a temperature of 90° is to be regarded with suspicion, and a monthly mean of 80° calls for inspection. The average daily difference between the highest and lowest temperatures at or near sea level is from 10° to 14° according to the season of the year. The temperature of a particular locality will depend upon the elevation of the place. Owing to the small land areas of the different islands the rate of decrease in temperature due to altitude is practically that found in ascending in the free air, namely 1° F. for every 300 feet vertical ascent. The altitudes of some of the mountain peaks of the islands place their summits within the limits of perpetual snow. The crests of Mauna Kea and Mauna Loa are seldom entirely free of snow. The rainfall of the islands follows the regimen of tropical islands similarly situated with respect to the prevailing winds. The key to the rainfall is altitude and the prevailing winds of the region and the season. The rainfall is plentiful wherever the land rises sufficiently to be a barrier to the winds of the region. At sea level the rainfall is relatively small, but it increases rapidly with elevation up to 6,000 feet, and then decreases. From the orography of the islands the greatest variety of rainfall distribution is observed. On Hawaii the average annual rainfall varies from 140 inches at Hilo on the east coast to less than 30 inches on the west coast. On Oahu a more striking difference is observed. At Honolulu, 50 feet above sea level, the average annual fall is 38 inches, while about 15 miles east, at Nuuanu, 850 feet above the sea, the average is 132 inches, and less than 25 miles west, in a sheltered valley, the rainfall is only 15 inches. Even on the same plantation, the rainfall on one part will be abundant for the most luxuriant tropical growth and on the other part irrigation will be necessary to grow an ordinary crop. The porosity of the soil is, as already stated, great, so that notwithstanding the torrential downpours that occur on the elevated lands, the soil remains free from dampness. The water runs through it with great rapidity. The average relative humidity of the islands is about 75 per cent. of saturation, varying somewhat with the direction of the wind. It is greater with southerly and less with northerly winds. The prevailing winds of the archipelago are the northeast trades. For nine months, March to November, they blow with almost unfailing regularity. During the other three months the islands are more or less under the influence of the southwest antitrades. These antitrades are the disagreeable winds of the islands. It is only during their prevalence that the sultriness and oppressiveness of the tropics become manifest.

Health.—Statistics as to the prevailing diseases of the islands are not plentiful. Leprosy, an imported disease, is now endemic among the natives. Great care, however, is taken to prevent its ravages and stamp it out. The government years ago established a leper colony on the high table-land of Molokai, and hither all afflicted are sent and carefully cared for.

Among the causes of death given in a recent report for the city of Honolulu, phthisis claimed more than 10 per cent.; old age and heart disease about 7 and 6 per cent. respectively. Among other causes enumerated were pneumonia, bronchitis, diarrhœa, and paralysis.

W. F. R. Phillips.

HAW, BLACK. See *Viburnum Prunifolium.*

HAY FEVER is the popular title for an annually recurring affection which involves the mucous membranes of the ocular and respiratory tracts and is associated with certain symptoms which can be accounted for only by reference to the nervous system. It, or a very closely allied disorder, occurring during the early summer in England, was first described by Bostock in the Medico-Chirurgical Transactions for 1819, under the name of *Catarrhus Æstivus;* and in his work upon the affection now treated of, Dr. Wyman advocates the use of the term *autumnal catarrh* as more correct, and not involving the absurdity of associating a disease with an impossible cause—for the season of hay-making, in the United States at least, is long past before hay fever makes its appearance. But the title has become so embedded in the popular mind that there seems to be no escape from what is indisputably a misnomer. Basing the suggestion upon the view that the affection depends upon engorgement of the nasal mucous membrane, with associated reflex nervous symptoms, Mackenzie, of Baltimore, has proposed as a new name *coryza vasomotoria periodica*, which has the advantage of accuracy at least.

The peculiarity of the affection is its annual recurrence, in the same individuals, with almost ludicrous exactness in point of time, throughout, in many instances, the years of a long life. Thus an examination of the narratives of their cases, written by those who suffer from *hay fever*, will reveal the fact that the attack occurs upon the same day, or even the same hour of the day, in each year, and in none is there a variation of more than a few days. This regularity of return is apparently but little affected by the peculiarity of one year as compared with another. Whether the season is wet or dry, whether as a consequence vegetation is rankly growing or falling into decay, appears to make no difference. Another singular fact is that the sufferer from this disease in Philadelphia or Baltimore may rest assured that, at the precise time he begins to feel the approach of his enemy, his fellow-sufferer in a place as far removed geographically as Boston is subject to attack at the same time, though his climatic surroundings are quite modified.

The attacks are, however, not of similar severity each year, but will vary somewhat. Why this should be so it is hard to determine; but it has been observed that when, as in 1885, there is a prolonged drought in the early summer, succeeded by heavy rains leading to a revival of vegetable growth in the month of August, the season is likely to be a bad one for sufferers from autumnal catarrh.

Age appears to have nothing to do with this affection, some persons experiencing their first attack as early as in their third or fourth year, while others escape the formation of so undesirable an acquaintance until quite mature life. It is a curious fact, revealed by an examination of Dr. Wyman's table of eighty-one cases, that males are more likely to be sufferers in early life than females; which is in accordance with the observation of the writer, although there is no particular significance in it, so far as his knowledge goes.

Another peculiarity of this disease, and one which has been noticed by many observers, is its greater prevalence among those who are not compelled to resort to manual labor for a livelihood. Not that it does not occur in this latter class, for some such are recorded by Wyman, and many have fallen under the observation of the writer of this article and others; but that it is of comparatively rare occurrence among the laboring classes is a patent fact. The writer's experience leads him, however, to think that this difference is becoming less marked of late years, and that not only is the aggregate number of cases increasing, but that periodical catarrh is extending among classes which were at one time in a great degree exempt from its visits.

Having now referred to some of the peculiarities of this troublesome affection, I may next proceed to a description of its *symptoms* and *course*, as ordinarily observed.

About the middle of August the patient experiences itching of the eyes and pharynx, which at times is intense, and is accompanied by most inordinate and frequent sneezing. The irritation of the eyes and throat appears to be without cause, but the sneezing seems to be provoked by bright light, cool currents of air, or some exposure to the causes which ordinarily are regarded as provocative of catarrh. At first these attacks are infrequent and of moderate severity, but they soon become more severe and more frequent. On first getting up in the morning, while dressing, and often during breakfast, the attacks of sneezing are prolonged, and altogether unaccompanied with the grateful sense of relief which in other circumstances is experienced in connection with this manifestation. Every exertion increases these symptoms, and there accompanies them that general feeling of discomfort, with slight acceleration of pulse, which have earned for the disease the misnomer of hay fever; yet there is no record showing the existence of a higher temperature. The amount and severity of these symptoms will vary somewhat with different years, but they will always exceed in both respects those observed in ordinary coryzas.

Usually symptoms of bronchial irritation manifest themselves in about a week, and dryness and injection of the fauces are followed by a tickling cough, accompanied with but little expectoration. After a time the cough becomes more severe, paroxysmal in character, and is often accompanied with much soreness in the chest, which is somewhat relieved when expectoration is established. Like the coryza, the bronchitis varies much in intensity in different individuals, and somewhat in the same persons in different years. In some it does not exceed in severity that attending a mild cold, in others it becomes a most serious affection, and is occasionally accompanied by expectoration of mucus streaked with blood. The observation of the writer, however, has not brought him in contact with a case in which true pneumonic sputa were present, although he is familiar with one in which the expectoration has on two occasions very nearly approached that character. The physical signs on auscultation are those of bronchitis.

In many cases, after a most harassing experience extending over ten days or two weeks, both the coryza and the cough lessen in severity. The former almost entirely disappears, and while the latter may persist as a most exasperating tickling, especially at night, convalescence passes into complete recovery, the whole course of the disease having lasted for from three to four weeks.

But in the vast majority of cases the advent of the cough is accompanied by asthmatic symptoms of more or less severity, and in very many these symptoms cause everything else to appear as insignificant. Indeed, more severe asthma than accompanies some cases of autumnal catarrh is rarely, if ever, seen.

The first asthmatic symptoms generally appear about the 25th of August, and are often brought on by a spell of coughing, some unusual exertion, or in many cases by the change of wind accompanying a thunder-storm. From the time of their first appearance these symptoms do not entirely disappear until the conclusion of the annual attack, which is ordinarily about the end of September, although in some cases prolonged until a later date. All the time there is more or less difficulty of breathing, accompanied with true asthmatic râles. Upon percussion the chest is more than usually resonant, showing the existence of at least a temporary emphysema; but upon applying the ear to its parietes, it is found to be filled with dry cooing and sibilant murmurs, reminding the listener of nothing so much as "a bag of whistles." Indeed, these sounds are generally readily perceptible at a considerable distance, and become more marked at the approach of a paroxysm.

Than a severe paroxysm of dyspnœa, such as is frequently seen in these cases, there is scarcely anything harder to bear or more painful to witness. The approach of the attack is signalled by an increase in the loudness of the chest murmurs, and by increased difficulty of breathing. The patient cannot lie down, and, indeed, very soon cannot lean back in his chair. Sitting or standing, the patient will seek a firm surface on which to lean, and planting his elbows firmly upon it for support, will gasp for breath. The sonorous chest sounds lessen, the inspiration becomes comparatively lengthened, and the expiration much hurried. The collar will be unbuttoned, the face assume a yearning and almost despairing expression, the eyes be suffused and tearful, while the efforts of the arms, shoulders, and all of the muscles accessory to respiration are most severe and accompanied with a very copious perspiration. The sense of fatigue is extreme, and to the expression of anxiety is added one of intense weariness; but the efforts are unrelaxed, for, though wellnigh useless, they are involuntary and cannot be lessened by any effort of the will. No sounds whatever come from the chest, and while the patient feels as if he was breathing in vacuo, the inexperienced spectator will think that actual suffocation is impending. If not interfered with this state of things may last for from a few minutes to several hours. Gradually there will be a return of wheezing noises in the chest, the respiration will become somewhat less shallow, and the sense of suffocation less acute; and if the improvement continues the expression of relief becomes marked upon the face, and the sufferer drops into sleep without much reference to the position he occupies.

But the relief experienced is very generally only partial, and the respiration continues laborious and oppressed, while exercise or any physical effort is impossible without immediate aggravation of the symptoms. This state of things continues until the end of the season, though lessening gradually with the diminution of the bronchitis and the disappearance of the cough. The writer has known this asthmatic period to last for from three to six weeks, during which time the patient could not go up and down stairs, could not sleep at all without the aid of anodynes, nor indulge in the slightest dietary indiscretion. The eating of large amounts of food late in the day, or of indigestible food at any time, is likely to bring on an acute paroxysm, and the same result is very apt to follow a prolonged spell of coughing. Very often sleep can be obtained only in the upright position, either in a chair or propped up in bed with a large number of pillows.

In many cases of periodical catarrh the asthmatic symptoms never attain the severity of those which have been described, but they are present in a more or less modified form in the majority of instances, especially at night. As has been said, when the asthma is a marked feature in the individual cases it overshadows all other symptoms, and we shall not obtain the vividly thrilling descriptions of the sufferings from catarrh, which encumber books upon this special topic, from those who have severe asthma. They will express themselves as quite ready to bear the annoyances of the most violent coryza and the most irritating cough, if they can only secure immunity from the dyspnœa and orthopnœa which they have learned to dread.

After the middle of September there is a gradual declination in the severity of all the symptoms, and by the end of the month they have in great measure disappeared, though in the severer cases there may remain a tickling cough and the liability to attacks of oppression to a much later date. Indeed, it would seem, in the more severe cases, and especially in those which suffer much from asthma, as if there was a tendency to a gradual prolongation of the after-period, so that throughout the winter any severe cold is liable to be complicated with asthmatic symptoms. That this should be the case is quite natural in view of the causal relation existing between asthma and true emphysema. Yet permanent emphysema is rarely present, probably owing to the shortness of the attacks, and to the fact that most patients enjoy a sufficiently long period of health between them to prevent organic changes taking place in the elastic lung tissue.

Observation has convinced the writer of this article that the recurrence of these attacks, unmodified by effective treatment, tends to fasten the habit more firmly upon the system, as well as to increase the length of the after-period. His experience has taught him that if the season is anticipated by a suitable change of residence, and the severity of the attacks modified by appropriate treatment, the force of the annual habit is lessened, and while it may not be entirely obliterated, the acuteness of the periodical attacks will be diminished. It is this fact which leads him to urge careful attention to those cases which occur in children, as in them there is more hope of being able to attain good and permanent results. As a general thing, the first attacks are less severe than the succeeding ones, and there would seem to be more encouragement to expect good results by prompt and *early* treatment.

When we come to consider the *nature* and cause of this curious affection we enter upon a wide field, and one upon which most conflicting theories contend. That this should be the case is natural from the absence hitherto of any researches throwing much light upon any anatomical peculiarities pertaining to the affection. That there are such peculiarities, however, at any rate associated with it, cannot be doubted in the face of the observations recently made by such authors as Harrison Allen, J. N. Mackenzie, Sajous, and others; but it is as yet too early to conclude with certainty that these anatomical peculiarities are undoubtedly the cause of the affection under consideration. According to these observers the subjects of "hay fever" are all alike in presenting certain peculiarities in the anatomy of their nasal cavities. According to Harrison Allen, the nostrils are obstructed by deflection of the septum, hypertrophy of the soft parts and bones, or turgescence of the mucous membrane, and always an undue prominence of the inferior turbinated bone. J. N. Mackenzie, Roe, Daly, Hack, and Sajous hold that there exist in these cases both an unusual development and an unusual excitability of the mucous membrane covering a well-defined sensitive area, which is known to be coterminous with the inferior turbinated bone. According to these observers the symptoms of periodical catarrh are reflexes induced by irritation of this area, in cases which possess at the same time abnormal vaso-motor excitability, and hence J. N. Mackenzie proposes the name of coryza vasomotoria periodica for the disease.

The theory of these gentlemen, though revolutionary in character, has much to recommend it, and is found to be in strict accord with many of the observed facts in these cases. Yet in some respects it is not altogether satisfactory, especially when the question of periodicity is considered, or when regard is had to effects often noticed when a change of climate, or rather of place, is resorted to. Thus it is difficult to see how turgescence of the erectile tissue over the turbinated bone should occur, or, at any rate, produce serious effects, only at one season of the year. Then it is certainly going too far to account for the benefit secured at certain seashore places simply by the tonic effects of the sea air upon the nervous system, and to point to the well-established fact that a land breeze is injurious, and claim that it is so only so far as it is relaxing and enervating. At every place on the seashore there are alternating sea and land breezes; yet relief from autumnal catarrh is experienced at but few of them, and those that experience has proved to be suitable places of resort are such as by their topography receive no breeze from the land until it has passed over a considerable expanse of water.

But these observers, while maintaining the anatomical and nervous basis of the disease, do not deny that pollen may be one source of irritation among many others, and even should the theory they propose not be at present reconcilable with all the facts in any given case, it is reasonable to anticipate that further observation and closer study may tend to complete elucidation of it. Hitherto there has been nothing more definite than the supposition that the affection was produced by one or more kinds of pollen acting upon a personal idiosyncrasy —the latter term, of course, being only a convenient expression to cloak ignorance. This theory has been upheld by the majority of writers in the past, and is still contended for by Morell Mackenzie, Blackley, and many others. According to these writers, at a given season there is a large amount of pollen grains afloat in the atmosphere, which serve as the exciting cause, in cases possessing that personal peculiarity or idiosyncrasy wherein lies the true essential characteristic of the disease. When tested by experience the theory is found to fit in almost every particular.

That there is some peculiar atmospheric condition present only at a given season would seem to be proven by the fact that in the vast majority of cases there is an entire absence of symptoms at all other times. That this condition is imparted from the vegetable kingdom would seem proven, because almost all cases are benefited by a residence, during the time, either at certain places among the mountains, at certain seashore resorts separated from the mainland, where there is little vegetation, or most certainly during a sea voyage. The malign influence of vegetable exhalations in these cases receives support also from the well-known fact that the kindred affection known as "rose-cold" seems to be largely dependent upon such irritants. The writer is acquainted with one gentleman who suffers acutely in September, but is perfectly well in June. His mother-in-law, for very many years and until her death, suffered in precisely the same way, and was also well all the early summer. They were both relieved by removing to Beach Haven, on an island off the New Jersey coast only six miles distant from the home of the mother-in-law. In this coincidence there is, of course, nothing peculiar; but two of the brothers of the gentleman mentioned, with his wife and sister-in-law, have been severe sufferers from acute coryza in June, and are all quite well in September. We have here a group of six cases, five of whom would be properly described as very far removed from the category of nervous persons, who have for many years suffered periodically, in all of whom relief is, at least, associated with the comparative absence of vegetable influences. Of the June cases, two were always better in town, and the attack was not so severe as to require other measures of relief; one is free from attack at Beach Haven; while the fourth, whose attacks are the slightest, gets comfort by keeping most of the time in the house. In none of the June cases is asthma present; but all have noticed great aggravation of their symptoms when exposed to various kinds of pollen, notably that of the horse-chestnut, the ailanthus, and the scented honeysuckle. In one of the June cases, and in one of the September cases, prominence of the inferior turbinated bone has been noted.

The object in citing these cases is not to bolster up the old and exclusive pollen theory, but to submit them merely as cases which show the difficulty which presents itself to any one who attempts a close and exclusive definition which will suit all cases.

Advocates of the purely nervous and anatomical theories maintain that their theory is supported by the results of treatment, and this will be spoken of more at length in its proper place; but the claim is as yet not fully substantiated, and quite a number who have undergone local and tonic treatment are known still to suffer from their old enemy. Whether this will continue to be true when they have undergone a *sufficient* number of applications to the nasal mucous membrane remains to be seen, but it is not as yet proved. It is still *sub judice*, and is subject in some measure to the well-known disposition—or idiosyncrasy shall we call it—possessed by many hay-fever patients, to be cured in succession by many forms of treatment. At the present time (1901) a resort to local treatment is comparatively safe, the results not having proved so satisfactory as was at one time expected.

In his recent work on hay fever, Sajous recognizes the difficulty of precise and exclusive definition, and formulates a theory which is comprehensive, and which may at least serve as a working hypothesis until more extended and complete observation furnishes us with one that is entirely satisfactory. According to this author, hay fever requires, first, an external irritant; second, a predisposition to become influenced by this irritant; and, third, a vulnerable or sensitive area through which the irritant may exert its influence.

It may be safely concluded that autumnal catarrh is largely dependent upon some disorder of the vaso-motor nerves, that the sympathetic system is partially responsible for the trouble, and that many of the symptoms are true reflexes; but what is the precise character of the trouble is not known; undue excitability there may be, and probably is, but that tells us little more than the old term idiosyncrasy. It has, however, the great advantage of directing our treatment into a definite channel. While admitting the implication of the nervous system, it cannot, however, be concluded that pollen has no share in producing the disease. That it has a large and important part as an exciting cause, it seems impossible to doubt. On the other hand, pollen is not the only excitant, but dust, heat, electrical conditions of the atmosphere, and many other things share with pollen the ability to provoke an attack in properly disposed persons.

Treatment has hitherto been of two kinds, namely, palliative at home, or radical by removal to a locality which experience has proved to be exempt from the exciting causes of the disorder. While the former has been unsatisfactory—so much so, indeed, as to lead many sufferers from hay fever to disregard it altogether—there is no doubt that much can be done to lessen the severity of the attacks, and to mitigate the suffering they cause. Leaving out of view, for the present, the local treatment, so much lauded of late as the only radical one, the following line of procedure may be safely followed as rational, harmless, and as proved by experience to be beneficial.

The patient should lead a very quiet life from the beginning to the end of the period, avoiding exposure to draughts, the direct rays of the sun, and any exertion which may tend to quicken the circulation. He should pay particular attention to his diet, especially during the later hours of the day. By this it is not meant that he should go upon a low diet, but that he should avoid anything that is indigestible, or which during digestion gives off a large amount of gas, such as sweet potatoes or lima beans. In many cases watermelons act injuriously, and the individual powers of digestion should always be carefully considered. Keeping this last point in view, there is no reason why rich soups, meats, the less starchy vegetables, and many fruits, should not be indulged in. He will do well to have any peaches he may eat pared before they are brought into the room, and he will be wise if he eats nothing after the early hours of the afternoon.

For the conjunctivitis, or rather the ocular injection, which exists in these cases, a weak solution of brandy and water, or some other mildly stimulating collyrium, will prove most comforting. When obliged to go out in the day-time, dark-colored spectacles will afford considerable relief. Similar locally stimulating treatment will be found beneficial to the coryza. Weak solutions of quinine, of sea salt, or any other suitable substance, will afford temporary relief, and if attention is paid to the specific gravity of the solutions by the addition of a saline, so that they approach that of the blood, they can be frequently repeated without injury, and with positive benefit. In the use of hydrochlorate of cocaine, there is every reason to expect decided benefit. Dr. Da Costa has found it useful in a number of cases, when applied to the nasal mucous membrane, and there would seem to be good grounds to anticipate advantage from its further use in solutions of varying strength. The danger of acquiring the cocaine habit by these applications should, however, not be lost sight of. Stimulating gargles, such as vinegar and salt, are useful by temporarily allaying the intense itching in the roof of the mouth, and lessening the hyperæmia of the mucous membrane of the fauces and pharynx.

When the bronchitic symptoms appear, the use of mild expectorants with opium will be found decidedly useful in allaying the cough, even though they do not abolish it altogether. Neither physician nor patient should allow the fact that the disease is annually recurrent, and that the predisposition cannot be destroyed, to prevent the use of ordinary remedial measures to palliate the severity of the symptoms. Very many cases will be benefited by some such prescription as the following: ℞ Morphinæ sulphatis, gr. i.; extract. belladonnæ, gr. ij.; extract. prun. virg. fluid., syrupi lactucarii, āā fl ℥ i. Dose, a teaspoonful every four hours. Beyond the fact that they divert the attention of the patient, counterirritants applied to the chest do not appear to do much good, while they possess the disadvantage of sometimes provoking troublesome skin affections.

When asthmatic symptoms present themselves, opium, in one form or another, will be found to be by far the most efficient remedy. Two or three doses of one-fourth of a grain each, taken two hours apart in the evening, will be found to diminish the spasmodic tendency most materially, and by cautiously increasing the dose from time to time, or by changing the form of the drug, it will be found possible to maintain the good effects throughout the time of the attack without resorting to a very large dose. In recommending this method of treatment the physician should carefully weigh the risk that the patient runs of acquiring an evil habit, and should always insist that it should be pursued, under competent medical oversight, only when the discomfort is severe. He should, above all, urge its abandonment at the earliest possible day. He should always bear in mind the fact that, while the immediate comfort of the patient may be promoted, his ultimate well-being may be seriously imperilled by a drug which is so potent for both good and evil.

When the physician is called to witness one of those extreme attacks previously described in this article, when the orthopnœa is complete, and the sufferings of the patient are far greater than are usual at any death-bed, he will find that in his hypodermic syringe he possesses an implement of almost magical power. The injection beneath the skin of one-fourth or one-third of a grain of sulphate of morphine will, in the vast majority of cases, afford complete relief in a very few minutes. The practice of the writer has been to use seven minims of Magendie's solution, and he has never witnessed more marvellous effects from any medication. Generally within fifteen minutes the spasm has entirely disappeared, and the patient has fallen into a quiet sleep. Rarely, and only in those cases in which the remedy has been often administered, he has had to use a supplemental injection of four or five minims.

Smoking various kinds of cigarettes, burning saltpetre papers, or some of the various quack compounds so extensively sold often afford some relief, generally just in proportion as an anodyne has been incorporated in the mixture. Chloral will afford relief in some cases, but, apart from the danger which attends its use, it is much less efficacious than the course of treatment above indicated. When resorted to it may be advantageously combined with full doses of one of the bromides. These last-mentioned remedies may often be used with benefit. Twenty grains of the bromide of potassium, repeated every hour until a drachm has been taken, will frequently secure a quiet night. The bromides and chloral may be usefully added to, or alternated with, opiates. Musk, camphor, asafœtida, stramonium, and very many other remedies addressed to the nervous system, have been recommended, and may be tried sometimes with advantage, both from their own intrinsic power, and from the aid they lend to the effort to keep within bounds the dose of opium necessary for the control of spasm.

The treatment above indicated will enable sufferers from hay fever to exist with a minimum of discomfort at home, but in those cases which suffer much from asthma it will be a period of confirmed invalidism at best, and they will long for more radical and more effectual means entirely to abolish the recurrence of the annual attacks. There are very many who merely suffer the inconvenience of a severe coryza and an annoying catarrh, but who are able to go about and attend to business, with discomfort, indeed, but without interruption. Such cases may afford to consider whether they will continue satisfied with palliative treatment, or seek that which, while more severe, is certainly more effectual. But the patient who has had one attack of severe asthma will share the anxiety of his friends that he may escape another such, and will be willing to make great efforts, to endure many discomforts, aye, go even to the ends of the earth, if he may only thereby avoid another attack.

Fortunately, a change of location can be recommended with confidence. Experience has proved that immunity is enjoyed at Bethlehem, and many other localities in the White Mountains, as well as at other elevated locations; at Beach Haven, N. J., Fire Island, N. Y., Halifax, Nova Scotia, and a few other places on the seashore; or, better than all, at sea, out of sight of land. It would be out of place, in an article like the present, to go into a discussion of the reasons for the immunity enjoyed under the circumstances, yet it may be well to refer to certain facts as tending to an elucidation of the matter, or at least as helping us to a knowledge of the conditions essential to immunity. Why certain mountainous regions should be exempt and others not, is not known. It cannot be elevation, for all elevated regions do not afford relief, while those which do are often less high than those where no relief is obtained. It cannot be altogether the absence of pollen, for none of the localities proved to be beneficial are entirely destitute of vegetation. Yet the fact remains, and it is idle to deny it, that autumnal catarrh is escaped at Whitefield, Franconia, Fabyan's, Crawford's, Mount Washington, Gorham, and many other places in the White Mountain region, at many places in the Adirondacks and in the Catskills, at the Straits of Mackinaw, and at some other points in the Northwest. When we come to the seashore, we find that Fire Island and Beach Haven are both situated upon islands of limited extent, somewhat removed from the mainland, and, so far as our present knowledge goes, it is only at places similarly situated on the seashore that exemption from hay fever is enjoyed. These islands are very low, Beach Haven not being more than eight or ten feet above high water. Nor is there an entire absence of vegetation, there being an abundance of marine plants, and the upland flowers, though few in number, are yet amply sufficient to supply pollen to a disastrous degree, did it possess the virulent properties supposed to belong to it by Morell Mackenzie and Blackley. Yet, as was pointed out by the author of this article some years since, very many persons entirely escape their annual attacks of hay fever at Beach Haven, and all enjoy a greater or less measure of relief. While the wind is from the sea complete immunity is enjoyed; when it comes from the land some inconvenience is experienced, but the attacks are always of modified severity.

Although, therefore, it is difficult or indeed impossible to give a satisfactory explanation of the reasons why certain places are safer resorts for sufferers from autumnal catarrh than others, it is well to advise such cases to make trial of one of them, making the selection according to the dictates of individual convenience and inclination. But it is important, when the patient goes to one of these resorts, that he go *before* the time of the expected attack, and observe ordinary hygienic precautions while there. Personal observation leads the writer to believe that it is of importance to anticipate the attack by several days, and that, when it has once begun, it is much more difficult to get rid of it. Yet many persons will arrive at their safe harbor suffering acutely, and find complete relief in a few hours. Nourishing food, light woollen clothing, thin flannel next the skin, the avoidance of undue exertion, and rational medical treatment for any symptoms which arise, will give comfort, even though the exile—for an exile it is when enforced from year to year—may be inconvenient and hard to bear. The writer would especially urge the importance of sending children to some safe place, as he is increasingly convinced that, if there is any hope of breaking up what may be in part a systemic habit, it may be most reasonably indulged in the case of very young persons. To accomplish this is worth every effort, for while autumnal catarrh is not a disease endangering life, and the suffering attendant upon it may be alleviated or borne, its annual recurrence does most seriously interfere with all the avocations of the individual, whether he remains at home or seeks refuge in an exempt locality. Experience would seem to show further that when complete exemption is enjoyed for a series of years, recurring attacks exhibit less severity.

During the years which have passed since this article was written its author has met with quite a number of cases in which the disease has practically disappeared in those who persistently visited exempt localities for a series of years, and his conviction is strengthened that when the habit of the system is interrupted by such means there is a distinct tendency for the disease to wear out (May, 1901).

The new pathological views to which reference has been made, and which identify the disease in question with certain abnormalities and pathological changes within the nasal cavities, have led to local treatment of greater or less severity, instituted with a view of getting rid of the cause entirely. Any abnormal prominences or growths connected with either the mucous membrane or the bones are attacked by the snare or galvanic cautery and destroyed, or if the trouble is found to consist in turgescence of the erectile mucous membrane, various stimulating applications are resorted to, and with most satisfactory results to those who have used them. The method is recommended by such capable observers, and specialists so skilful in their departments, that it is certainly worthy of more extended trial. As reported, the results have been very good, but it is yet too early to utter any *ex-cathedra* opinions upon the subject. Several who have undergone the treatment referred to have fallen under the writer's notice. Some have thought they were benefited, others that they were not improved, and one, at least, believed that he was worse than before. Most of the cases were met at a hay-fever resort. It is but right to add that some of the cases had not undergone the number of local applications which their attendants thought were necessary to work a complete cure. While the application of mechanical and operative measures may be safely tried within certain limits, there would seem to be danger of carrying the practice too far. It should not be forgotten that extensive tracts of cicatricial tissue may become the seat of more serious disease than hay fever. For the latter we have a tolerably certain and satisfactory palliative, if not a permanently radical cure, in temporary change of residence, while at present operative interference is undertaken only with the *chance* of permanent relief. As has been already stated, this form of treatment is less frequently resorted to at the present time, having proved disappointing to its advocates.

Those who desire to familiarize themselves with the natural history of hay fever will do well to consult the admirable work, "Autumnal Catarrh," by Morrill Wyman, M.D. (New York, 1872), in which they will find the best account of the disease and the most careful study of places where exemption from its attacks exists. Those who desire to know all about the pollen theory, and the extent to which it can be carried, will do well to consult "Experimental Researches on the Causes and Nature of Catarrhus Æstivus," by Charles H. Blackley, M.R.C.S. Eng. (London, 1873), and "Hay Fever: its Etiology and Treatment, with an Appendix on Rose Cold," by Morell Mackenzie, M.D. (London, 1885). This last book is most vigorously reviewed in the *American Journal of the Medical Sciences* for October, 1885, by Dr. John N. Mackenzie, of Baltimore, who has also contributed several papers bearing upon hay fever to various journals, in which he ably upholds the neurotic and anatomical theory of the disease. An able and suggestive paper will be found in the number of the *American Journal* for January, 1886, in which Sir Andrew Clark maintains very similar views, but would account for the asthmatic spasm by temporary and sudden congestion of the mucous membranes rather than by muscular constriction of the bronchial tubes. In "Hay Fever and its Successful Treatment by Superficial Organic Alteration of the Nasal Mucous Membrane," by Charles E. Sajous, M.D. (Philadelphia, 1885), there will also be found an exposition of the modern views, and details of the treatment recently so highly lauded for this most troublesome affection. Other papers upon the subject will be found scattered through the journals by Daly, Roe, Allen, Bosworth, Da Costa, Beverley Robinson, S. S. Cohen, and Hack. The work of Dr. W. C. Hollopeter, of Philadelphia, is among the more recent contributions to this subject.

Samuel Ashhurst.

HAYWOOD WHITE SULPHUR SPRING.—Post-Office.—Waynesville, Haywood County, North Carolina. Hotel and cottages.

Access.—From Asheville, viâ Murphy branch of the Western North Carolina Railroad, thirty miles west. The location of these springs is in the heart of the Alleghanies at the foot of the Great Balsam Mountains, where the peaks tower 5,000 to 6,000 feet in height. The altitude at the springs is about 2,800 feet. The surrounding scenery is of surpassing beauty, not excelled in rugged grandeur east of the Rockies. During the summer and autumn seasons the weather here is generally delightful, the temperature ranging from 56° to 80° F. The hotel is usually crowded with visitors at these times, some of them from remote points. There are two springs, one sulphur, the other iron. The temperature of the water is 54° F. No complete analysis has been made, but we are informed that the waters contain, besides sulphur and iron, salts of sodium, potassium, and magnesium. The present hotel, a large and commodious brick building, with surrounding wooden cottages, is located on the banks of the Richland River, a beautiful trout stream. Numerous attractions in the way of shooting, fishing, archery, tennis, bowling, and billiards are at the option of the guests. The medical properties of the water have been amply attested, especially in chronic functional disturbances of the liver, stomach, and kidneys. Rheumatism and neuralgic troubles are benefited by the hot baths.

James K. Crook.

HEADACHE.—Headache is a frequent manifestation of the most varied disorders of the nervous system and of other organs. Being merely a symptom of so many different morbid states, it cannot be consistently characterized or described as a disease, although it is occasionally of such a nature as to possess the significance of an independent affection.

It may be so fleeting or transient as to be more or less ignored by the patient, or it may attain such a degree of severity or persistency as to lead the sufferer to seek medical advice. Familiarity with its various forms is essential, and it is necessary always to bear in mind that headache is a frequent accompaniment of many constitutional diseases. Hence a description and classification of headache with suggestions as to the means of determining its causation must prove of great practical value. According to many modern observers, we know almost nothing of the structures in which the pain of headache is felt or of the mechanism of its production. As the meninges, especially the dura and a large area of the cranium, receive their sensory supply from the terminal sensory branches of the trigeminus, and as the meninges are also supplied by branches of the sympathetic nerve, it is reasonable to assume that headache is the result of direct or indirect irritation of these nerves.

Psychical disturbances, in the form of depressing emotions such as grief, worry, fright, etc., often produce headache; in such instances it must be due to processes originating in the higher cerebral centres through which superficial pain is perceived. Headache must not be confounded with true neuralgia in which the pain is paroxysmal in character and directly limited to the course of the nerve and its distribution. The idea that the location of the pain in any particular region of the head is always directly related to some special underlying, adjacent or remote pathological process (excepting pericranial inflammation), has not been substantiated by clinical experiences.*

No definite rules can be laid down in regard to this matter that will apply in every case. It may be said, however, after perusal of the histories and observation of a large number of cases, that pain located at certain parts of the head occurs more often in this or that condition of disease. Such information, nevertheless, may prove valuable in suggesting certain lines of inquiry when found associated with other symptoms.

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* Recently, Head in his work on "Referred Pain" has endeavored to prove the existence of certain sensitive areas on the scalp in their relation to diseases of internal organs.

The headache may be confined to the forehead, to the vertex, the parietal, temporal, or occipital region on one or both sides; it may be unilateral as in migraine, or it may affect the entire head, and is then described as general or diffused, or it may occur in various combinations.

Patients usually describe the pain in the head, which frequently dominates all other symptoms, as acute, sharp, throbbing, darting, dull ache, boring, burning, stabbing, etc. It may be transient, paroxysmal, periodical, or continuous, and may vary in degree and location from time to time. As pain is a subjective symptom we can judge of its degree only by the *tout ensemble* of the individual and by its association with unmistakable physiognomical expressions and physical manifestations.

"Traditional psychology may be said to regard pain as a feeling, *i.e.*, a purely mental state or condition, with or more frequently without a physical basis in the nervous system. Physicians do not place much confidence in the patients' statement of the quality or character of the pain, largely because patients have not words, nor experience to prompt the words, in which to describe their pains. The description of pain by a patient seems to be directly proportional to (1) liveliness of imagination, (2) vocabulary, (3) experience" (Witmer). The description is often materially enhanced by the patient's gestures.

HEADACHE, for all practical purposes, may be divided into two classes—functional and organic. The so-called functional forms of headache are by far the more frequent, and include those resulting from various constitutional or psychical disorders, and from causes not situated in the skull or cranial cavity, excepting the disturbances of special-sense organs, such as the eye, ear, and nose, and dental caries. Some special forms of disturbance of the cerebral circulation may also be placed in this category.

The organic form includes all types of intracranial disease, whether vascular, meningeal, or cerebral, and disease of the cranial bones.

The functional forms of headache may be classified and subdivided as follow:

TOXÆMIC.	1. Retained excrementitious substances. 2. Products of defective metabolism. 3. Infectious germs or their toxins. 4. Various drugs. 5. Graves' disease.
NEUROPATHIC.	1. Neurasthenia. 2. Hysteria. 3. Epilepsy.
REFLEX	1. Ocular. 2. Gastric. 3. Nasopharyngeal. 4. Auditory. 5. Dental. 6. Uterine. 7. Sexual.
CIRCULATORY.	1. Hyperæmia. 2. Anæmia.
MIGRAINE.	

TOXÆMIC HEADACHE.

In which the blood is contaminated by various deleterious agents.

1. RETAINED EXCREMENTITIOUS SUBSTANCES.—(The absorption of decomposition and fermentation products developed in the alimentary canal, or the reabsorption of retained excrementitious substances.) (*a*) Constipation. (*b*) Intestinal indigestion. (*c*) Gastric indigestion. (*d*) Uræmia.

(*a*) *Constipation;* (*b*) *Intestinal Indigestion.*—In a very large majority of instances in which headache is complained of, it is due to toxæmia resulting either from constipation, or from intestinal or gastric indigestion. The clinical fact has long been established that auto-intoxication of intestinal origin plays an important rôle in the production of headache, migraine, and vertigo, but such symptoms are evidently more or less dependent upon individual susceptibility. Constipation is not incompatible with apparent health, for some persons may be constipated for a week or more at a time without any complaint of digestive trouble or headache. For this reason, the objection has often been made to the hypothesis of auto-intoxication of fæcal origin. On the other hand, Bouchard, who has made a special study of this subject, believes that constipation should be regarded as a protection against intoxication, and says: "it supposes that all that is absorbable has been absorbed, the aqueous part with what was held in solution." The lengthiest argument, however, will not controvert the familiar fact that thorough purgation causes the rapid disappearance of the headache and associated symptoms in most cases of this character.

In these patients the headache is usually located in the frontal region, but is often diffused over the entire head. As a rule, it is not constant, and may or may not be associated with gaseous eructations.

In some it is accompanied by morbid somnolence during the day and heavy sleep at night, while in others insomnia is complained of. Occasional attacks of vertigo may also occur.

(*b*) *Intestinal indigestion*, with or without constipation, is more frequently productive of headache through autotoxæmia than as a supposedly reflex cause. The urine is often of high specific gravity and may contain an excess of indoxyl.

(*c*) *Gastric Indigestion.*—It would seem that gastric indigestion, on the other hand (although in some instances occasioning toxic absorption), is more likely to produce headache by reflex irritation through the pneumogastric nerve from fermentation of food and gaseous distention of the stomach. Thus, headache, possibly due to both causes, is frequently an accompaniment of dilatation of the stomach on account of the anomalous fermentations that are the consequences of it. The location of the headache is usually supraorbital or frontal.

(*d*) *Uræmia.*—Headache due to renal disease is of very common occurrence. Two forms are found in nephritic subjects—*uræmic* and *congestive*. Either one or both may be present in the same patient. The *uræmic* form is due to the retention in the circulation of excrementitious products, and may manifest itself in any type of kidney disease, whether acute or chronic. The pain is ordinarily situated in the occipital region, extending to the neck. It may or may not be associated with somnolence, nausea, or vomiting, etc., according to the degree of damage to the kidneys and arterial system. In some cases the headache may be accompanied by vomiting, vertigo, and optic neuritis, thus simulating the general cerebral symptoms of brain tumor. The *congestive* form arises in consequence of disturbed cerebral circulation in the presence of cirrhotic kidneys, with arterio-sclerosis, cardiac hypertrophy, and increased arterial tension. (See "Circulatory" form of headache.)

Puerperal Eclampsia.—Headache which is at times persistent and severe is often a premonitory symptom of a convulsive attack in this affection, and may be associated with delirium, excessive somnolence, mental hebetude, or insomnia. Œdema of the face and extremities is often present. This condition is generally regarded as acute renal disease of pregnancy, the headache and other symptoms being ascribed to some form of toxæmia not yet determined. Unless the urine is carefully analyzed, and the functioning power of the kidneys ascertained beyond question, the uræmic form of headache will often pass unrecognized, thus leading to unexpected and serious consequences.

2. PRODUCTS OF DEFECTIVE METABOLISM.—(*a*) Rheumatism. (*b*) Gout. (*c*) Diabetes.

(*a*) *Rheumatism.*—There are two forms of headache which occur in rheumatic subjects. One is due to autotoxæmia, the headache generally being diffused and similar to that occurring in other forms of toxæmia. The other is a true muscular rheumatism or myalgia located in the scalp and affecting particularly the occipito-frontalis muscle and its aponeurosis. The pain is increased by active or passive movement of this muscle, and it is common to obtain a history of other attacks of muscular rheumatism, affecting different parts of the body. These patients may also have suffered from acute or subacute articular rheumatism. The attack may last for from a few hours to several weeks. Like other forms of muscular rheumatism, it is brought about by exposure to cold. One of the worst cases seen by the writer occurred in a rheumatic subject after bathing the head in cold water, and then sitting at an open window for a half-hour or more.

(*b*) *Gout.*—Headache is frequent in gouty subjects. It may be due to toxic products of defective oxidation, or the result of vascular disease affecting the cerebral circulation. It is not unusually accompanied by interstitial changes in the kidneys. Gout, it is claimed, is merely a hypothetical condition and presupposes an excess of uric acid in the general circulation. The headache and the irregular symptom-complex often described as lithæmia is an atypical form of gout. There is more often a sense of pressure and fulness about the head than actual pain. Haig has called special attention to the association of such symptoms with retention of uric acid in the system. It is now well established that the headache, aberrant neuralgic pains, slight stiffness in the joints, and occasional attacks of acute gout, etc., arise in connection with defective metabolism. The most essential etiological factor is deficient oxidation resulting from overindulgence in unsuitable food and overdrinking, and the lack of sufficient physical exercise.

(*c*) *Diabetes.*—Headache occurring in diabetics is often accompanied by hebetude and depression of spirits. As a premonitory symptom of diabetic coma, it is soon followed by delirium and dyspnœa. The prevailing theory is that the latter form of intoxication is due to the presence of acetone in the general circulation.

3. Infectious Germs or their Toxins.—(*a*) Acute infectious diseases. Headache is frequently a prominent symptom in the early period of all acute infectious diseases. It is usually described by the patient as a generalized or frontal headache. As an initial symptom of typhoid fever, it is sometimes so severe and persistent as to demand special attention. The pain is often located in the occiput and back of the neck. It may be accompanied by photophobia, retraction of the head, and muscular twitching, thus simulating meningitis. In the early stage of smallpox, the intense frontal headache is accompanied by pains in the back and limbs. The same may be said of the grippe. General headache also occurs in the early period of acute croupous pneumonia and may simulate meningitis until the lung trouble has clearly developed. During the febrile stage of malarial intermittent or remittent fever, violent headache is often present. In general, it may be said that headache occurs in all conditions accompanied by fever. As a routine practice, the temperature should be taken in every case of acute headache. The character and frequency of the pulse, and the presence of fever are always suggestive of the probably infectious or inflammatory origin of the trouble.

4. Various Drugs.—(Nitrite of amyl, nitroglycerin, alcohol, tobacco, coffee, lead.) *Nitrite of Amyl* and *Nitroglycerin* will be mentioned under the head of "Disturbances of the Intracranial Circulation."

Alcohol.—Headache is often due to acute or chronic alcoholic poisoning. The nervous system is at times so sensitive that a small dose of alcohol may produce violent but transient general headache of a congestive type. Very frequently, after large doses sufficient to produce heavy sleep, the individual awakes with a severe headache the result of such indiscretion. This picture is unfortunately so familiar that it requires no further elaboration. Chronic alcoholic poisoning is often the cause of daily or constant headache. The headache is commonly due to a combination of causes, such as toxæmia, interference with the digestive processes, and cerebral arteriosclerosis. It is often accompanied by cirrhotic changes in the liver and kidneys, and by many of the attendant phenomena of these conditions.

Tobacco.—The habitual and excessive use of tobacco may be the indirect cause of headache, through its deleterious action on the digestive organs, its interference with the cardiac rhythm and the cerebral circulation, and the ultimate production of neurasthenia.

Coffee.—In some individuals the injudicious and excessive use of coffee is productive of headache and a sense of fulness in the head.

Lead.—Headache due to the toxic action of lead is a comparatively rare symptom. In some cases of chronic lead poisoning, however, headache does occur, and its cause must be recognized. It is probably due to the direct action of the lead on the cerebral nerve centres, or indirectly through the production of pathological conditions in the liver and kidneys. A rare form of saturnism, which is productive of serious cerebral symptoms and which may terminate fatally, is known as "Lead Encephalopathy." In this condition the headache is usually severe, and is associated with vertigo and bilateral optic neuritis (which may end in complete blindness) and a series of symptoms simulating the presence of an intracranial tumor. The more severe forms terminate in convulsions, delirium, and coma.

5. Graves' Disease.—Recent studies regarding the pathogeny of the symptom group known as Graves' disease lead us to assume that the condition is due to autotoxæmia from hypersecretion of the thyroid gland, which is often preceded by sudden or prolonged depressing emotions. Headache is not common in this affection, but it is sometimes a troublesome symptom, and may be confined to one side. It is occasionally accompanied by a sense of throbbing in the head, a pulsating noise in the ears, and transient vertigo. The rapid action of the heart and cardiac palpitation, the presence of thyroid enlargement, exophthalmos, tremor and excessive perspiration, will lead to a correct diagnosis.

Neuropathic Headache.

1. Neurasthenia.—Headache is often an important symptom in neurasthenia, but it is not present in all cases. As a rule it is not general, but is commonly located in the frontal or occipital region, and is often accompanied by occasional vertigo and muscæ volitantes. The headache, which is usually slight in degree, is either continuous or occurs at brief intervals. In the majority of neurasthenics actual pain is not complained of, but the sensations in the head are described as the feeling of "a constricting band about the forehead," "fulness in the head" as if there was "something pressing from within against the skull," etc. Frequently it is a sensation of weight or numbness, and occasionally of throbbing. The headache and other sensations increase after fatigue, and are often diminished by rest. Difficulty in concentrating the attention is often present. As a result of these varied forms of cephalic paræsthesiæ, such patients are inclined more or less to indulge in excessive introspection. They often become morbid and apprehensive, dreading the possibility of a brain tumor or other serious cerebral disease. All of these symptoms are modified in proportion to the attention given them by the patient. The presence of other signs of neurasthenia, their development or increase through mental effort or emotional excitement, and the absence of evidence of organic cerebral disease, make the diagnosis clear.

2. Hysteria.—Headache that is confined to a small spot, which has for many years been described as "clavus," is comparatively unusual in this country, and occurs most frequently among the premonitory symptoms of convulsive hysteria. The scalp is sometimes so sensitive that the slightest touch is not tolerated without wincing. In the majority of cases of hysteria, however, the headache corresponds with that of neurasthenia. It may be limited to one side and thus simulate migraine. In some instances, it may be characterized as a veritable psychalgia. The peculiar character of the headache, its dependence upon the momentary psychical condition of the patient, its rapid disappearance or variation in degree, the favorable influence of suggestion or diversion, and its occasional association with other signs of hysteria (paralysis, spasm, convulsive attacks, disturbances of sensibility, etc.) enable us to make a correct diagnosis. The stigmata of hysteria are not always present.

3. EPILEPSY.—While headache cannot be regarded as a symptom of epilepsy, its occurrence is at times of great importance in the diagnosis of obscure cases. An attack of *grand mal* is often followed by severe general headache which may last for several hours. This fact is of value in interpreting the cause of the headache when it is mentioned as occurring in the early morning on awaking. It is at times indicative of a nocturnal epileptic attack, and the diagnosis is positive when such headache is associated with soreness of the muscles and joints of the extremities, a bitten tongue or mucous membrane of the cheek, and wetting of the bed.

REFLEX HEADACHE.

1. Ocular; 2. Gastric; 3. Nasopharyngeal; 4. Auditory; 5. Dental; 6. Uterine; 7. Sexual.

1. OCULAR.—Ocular defects, such as errors of refraction and insufficiency of the ocular muscles, are a common source of headache. The two conditions may be found in various combinations. It has been claimed that fully sixty per cent. of functional headaches due to errors of refraction are caused by astigmatism alone, or in conjunction with other forms of ametropia (De Schweinitz). The headache is produced by strain on the ciliary muscles, and frequently arises in connection with hypermetropic astigmatism. The pain may be situated in any part of the head, but it is most frequently located in the supraorbital region. It may be persistent in character, and is often aggravated by using the eyes. It is relieved temporarily by the instillation of atropine, which paralyzes the ciliary muscles, or permanently, by wearing suitable glasses.

Headache caused by insufficiency of the ocular muscles may affect any portion of the cranium, but is often located in the occipital region. It may immediately follow the use of the eyes, but usually this is not the case, the pain occurring at irregular intervals. At times it may develop into a typical attack of migraine, and is often associated with symptoms of neurasthenia. The claims of certain writers, that the lack of balance in the action of the muscles of both eyes is a prolific cause of headache and various forms of nervous disease, have certainly been much exaggerated. The headache arises as a result of repeated or continuous efforts to obtain and preserve binocular single vision. It is a fact well known to all ophthalmologists that so-called ocular headache does not occur in patients in whom there is a congenital or acquired absence of binocular vision, as such patients are known habitually to suppress the image in one eye. Hence, the causative element of "effort at binocular fixation" is negligible under such circumstances. This occurs with high degrees of strabismus; paralysis of ocular muscles; when vision is greatly diminished or lost in one eye; and when there is considerable difference in the refraction of the two eyes. When headache occurs in such people it is invariably due to some other cause. The writer knows of a patient with ocular headache from muscular trouble in whom the pain entirely disappeared after the accidental destruction of one eye.

The improved methods in the examination of the power and action of the ocular muscles, introduced within recent years, have led to a more accurate and thorough study of these conditions. Curiously enough, the muscular troubles which occasion the greatest amount of discomfort to the patient at times produce no evident changes in the gross appearance of the eyes. Hence it is only after the most careful and painstaking investigation that they can be discovered and rectified. This is accomplished either by the use of suitable lenses to neutralize any existing refractive anomaly, and thus indirectly influence muscular action, or by surgical operation, or both. There must be a peculiar individual predisposition to headache, for there are persons who have both muscular and refractive anomalies without any symptoms of headache.

Headache often results from inflammatory eye troubles such as iritis, glaucoma, etc. In iritis, the pain is generally supraorbital, but may extend to the whole side of the head. Acute inflammatory glaucoma is accompanied by violent pain radiating through the head from the eye. The headache occurring in these conditions cannot be classified as of reflex origin. It is due to direct inflammation of the ophthalmic division of the trigeminus.

2. GASTRIC.—(*Vide supra*) Gastric indigestion.

Headache Superinduced by Hunger.—In some individuals headache arises as a result of hunger. A delay of a few hours in the time of the customary meal causes general discomfort and headache which disappear at once when food is taken. This form of headache is probably produced through irritation reflected from the gastric mucosa, or from temporary impoverishment of the blood diminishing the nutrition of the cerebral sensory centres. Such individuals often manifest a peculiar susceptibility to headache from other causes, especially migraine.

3. NASOPHARYNGEAL.—Any of the following pathological processes may occasion headache: adenoids in the nasopharynx; polypoid obstruction to nasal breathing; lesions of the turbinated bones, especially of the middle and posterior parts of the inferior turbinate; spurs from the nasal septum; or intranasal synechiæ. Hence, headache is not an uncommon condition in mouth-breathers. The pain is ordinarily located in the temporal region or the forehead. When such abnormities are removed the headache has often been known to disappear.

4. AUDITORY.—Impacted cerumen has in rare instances been the supposed cause of headache. In middle-ear disease, the headache affects the vertex or is situated in the temporal or mastoid region on the same side.

5. DENTAL.—Caries of the teeth in the upper jaw is an occasional cause of headache.

6. UTERINE; 7. SEXUAL.—Headache occurring in patients with uterine or ovarian disease should not be looked upon as a symptom of reflex origin. It is merely one of many phenomena associated with a neurasthenic condition which so frequently accompanies intrapelvic disease in women. The headache frequently affects the vertex but is more often general, and is at times accompanied by tenderness of the scalp. Other causes are usually operative independently of any local uterine lesion. The morbid self-consciousness developed in many women who have or think they have uterine or ovarian disease, is often sufficient in itself to engender a depressive form of neurasthenia. The same may be said, *mutatis mutandis,* of affections of the male genito-urinary organs.

According to Head (Allbutt's "System of Medicine," vol. vii., p. 749) headache may be secondary to disease of the organs within the thorax and abdomen. The pains in the head may be very slight, but are always associated with scalp tenderness in certain areas. The degree to which these pains in the head intrude on the patient's consciousness varies greatly. Thus, sometimes he is quite unaware that the scalp is tender, and the associated tenderness is discovered only by examination. He may, however, complain of headache which leaves behind it a feeling of intense soreness.

CIRCULATORY HEADACHE.

1. Hyperæmia. 2. Anæmia.

Headache due to disturbance of the cerebral circulation in the absence of organic intracranial disease.

Headache is at times the result of hyperæmia or congestion of the intracranial circulation. It may also be occasioned by cerebral anæmia. When it is due to increased arterial supply it is called *active.* If it is caused by obstruction of the venous circulation, it is termed *passive.*

(*a*) *Active Hyperæmia.*—This condition has been described as "cephalalgia vasomotoria" by Eulenburg, and is due to paralysis of the vasoconstrictors permitting of distention of the vessels. It may be either acute or chronic, but it is most frequently acute. As a rule, in the severe cases, it is accompanied by throbbing and pulsating general headache, vertigo, tinnitus, muscæ volitantes, photopsia, insomnia, mental confusion, and delirium, all of which are made worse by lowering the head. There may also be photophobia and general hyperæsthesia. The face and scalp are red, and the conjunctivæ injected. There are fulness and throbbing of the temporal arteries, and contracted pupils. The pulse is full, and may be either slow or increased in frequency. Occasionally there is a slight rise of temperature. In some individuals, such attacks occur periodically. The severe forms of this condition are fortunately rare. In the milder degrees it is not uncommon, but the diagnosis may at first be doubtful. Somewhat similar phenomena occasionally occur in the early stage of acute leptomeningitis of the convexity. There may be considerable variation in the intensity of the process, hence the above described symptom-complex is manifested in varying degrees. The condition is usually due to mental overwork, emotional disturbances, alcoholism, excessive use of tobacco, onanism, and injuries to the head. It occasionally occurs as a sequel of sunstroke, and from sudden suppression of menstruation in plethoric women.

The writer has in several instances witnessed a similar but slightly modified array of symptoms occur periodically in young women after removal of both ovaries. A prototype of this group of symptoms can be produced by the administration of various drugs, such as nitrite of amyl, nitroglycerin, etc.

(*b*) *Passive Hyperæmia.*—Venous hyperæmia of the cerebral vessels is an important cause of habitual headache. It may be either acute or chronic, but is most frequently chronic. The pain is of a dull character, and is often accompanied by a sensation of fulness and heaviness in the head. The face and ears may be slightly cyanotic in the more pronounced cases. The attacks also vary in degree, the minor forms not being uncommon. Passive cerebral congestion is generally caused by mechanical hindrance to the return of blood from the head. Thus, it results from growths in the neck making pressure on the jugular veins, cardiac disease, pulmonary emphysema, and persistent cough, as in pertussis. It may also be produced by a tight collar, or by continuous flexion of the head. The headache and other symptoms are aggravated by straining at stool, coughing, sneezing, stooping, or muscular effort.

Cerebral Anæmia.—Anæmia of the brain, as a rule, is a part of a general condition of anæmia and malnutrition. It may be the result of arterio-sclerosis including disease of the coronary arteries. Whether the general anæmia be of a chlorotic nature or from loss of blood, it is almost always accompanied by headache. The condition of cerebral anæmia in which headache occurs, is generally of the chronic form. The headache may be frontal, vertical, or diffused, and is commonly of a dull character. It is often associated with attacks of syncope, tinnitus, dizziness, incapacity for mental work, depression, and irritability. The pupils are usually dilated. The headache often diminishes or subsides when the patient assumes the recumbent position with the head low.

MIGRAINE.

Definition.—This affection has also been termed "sick headache," "hemicrania," and "paroxysmal headache." It is a periodical neurosis occurring most frequently in women, and is characterized by paroxysmal attacks of severe pain usually confined to one side of the head, chiefly in the course of the fifth nerve. At times it is preceded by a variety of transient visual disturbances and paræsthesiæ, and followed by nausea and vomiting.

Symptoms.—The headache does not arise suddenly, but is generally preceded by premonitory symptoms, such as vague indisposition, restless sleep, irritability, depression of spirits, somnolence, sensation of fulness in the head, slight dizziness, etc., and, later, transient ocular symptoms may develop. The headache is dull and slight at first, but gradually reaches such intensity that it is often described as unendurable, and the patient is frequently obliged to go to bed. During the attack all of the senses become more acute, and there is general hyperæsthesia, the sufferer being disturbed by bright light or the slightest sound. The temperature is normal, and the pulse is either slightly accelerated or slow. Sometimes, on the affected side, the face is flushed and hot, the conjunctiva injected, the pupil contracted, and there is strong pulsation of the arteries; or the face is pale and the pupil dilated. But such phenomena are by no means constant; in fact they are quite rare. They usually alternate during the attack and are most frequently bilateral. The former has been interpreted as due to sympathetic vaso-motor paralysis (angio-paralytic), and the latter as being due to vaso-motor spasm (angio-spastic). Too much stress has been laid by some writers upon the value of such manifestations. They are so uncertain and variable that as a rule they are of no special clinical significance. The pain is usually confined to one side of the head. It may, however, affect either side alternately, or both sides may become involved at the same time, the pain varying in degree on the two sides. The left side is more frequently affected. At one time it may have its greatest intensity in the forehead, and at another time it may be situated in the occipital region. Nausea and vomiting generally take place either during the early part of the attack or toward the end. In some patients vomiting is absent. Polyuria occasionally occurs at the termination of the attack. When the pain subsides, sleep follows, and the patient awakes free from discomfort. The headache may last for from several hours to three or four days. Ocular symptoms constitute a prominent feature in a certain number of cases, but they do not occur in every attack. In the most common type of migraine they are entirely absent. The visual disturbances occur in the form of photophobia, blurring of vision, bright lights, vibrating or luminous sensations which commence over a small area and gradually widen out, the flashing increasing in intensity and often assuming a zigzag shape like the outline of fortifications (scotoma scintillans), hemianopsia and transient amblyopia or blindness. This type has often been termed "ophthalmic migraine."

Other abnormal sensations are also complained of, such as disturbed sensation in the extremities, numbness and tingling in the skin, as well as partial aphasia. The eye symptoms and paræsthesiæ when present almost invariably precede the headache (just as certain auræ precede an attack of epilepsy), and last for from a few minutes to half an hour. In rare instances, such sensory phenomena occur paroxysmally without the headache.

Etiology.—It is pre-eminently an inherited disease. The constitutional peculiarity which predisposes certain people to migraine is not clearly understood. That some persistent pathological condition must exist is quite evident. Many of the so-called reflex causes, such as uterine and menstrual disorders, eye-strain, dental caries, or nasopharyngeal disease, are frequently only coincidental conditions. Ocular defects are more frequently the cause of other forms of headache.

Indigestion and intestinal autotoxæmia are the most important acquired factors in the causation and persistency of the affection. Neurasthenia and hysteria, gout and various lithæmic conditions also play an important rôle. The constitutional substratum varies in different individuals. Among the exciting causes of attacks may be mentioned mental overwork and anxiety, excessive fatigue or exhaustion from any cause, constipation, errors in diet, menstruation, and emotional excitement.

Diagnosis.—It is differentiated from other forms of headache by its periodical and paroxysmal character, its usual limitation to one side of the head, and its association with transient visual disturbances and other evanescent sensory symptoms, and the absence of evidence of organic intracranial disease.

Course and Duration.—Migraine usually begins after the twentieth year, but it has been known to commence as early as the fifth or sixth year of life. The interval between the attacks varies from two weeks to several months, the length of time often being modified by treatment. During these intervening periods, the patient may appear perfectly well. In women the attacks seem to occur more frequently at or about the menstrual period. In the ordinary form it has a tendency to subside spontaneously about the menopause in women, and after the age of fifty years in men. This is not the rule, for it sometimes lasts through a whole lifetime. When the affection has persisted for several years, the attacks being frequent and severe, it usually leads to a general neurasthenic condition. It is thus commonly found in association with neurasthenia and hysteria. The ophthalmic form of migraine usually appears later in life, occasionally growing progressively worse, and it has been known to be the precursor of serious organic brain disease. Migraine has occasionally been found in conjunction with epilepsy. In such cases, the migraine attacks have at times alternated with the epileptic seizures or epilepsy has followed migraine which had entirely disappeared.

In rare instances, the attack of migraine is complicated by sudden paresis or paralysis of the third nerve on the same side. The ocular paralysis is usually transient and recurs in varying degrees in subsequent attacks of migraine. In many of the reported cases, the patients have eventually made a complete recovery both from the attacks of migraine and from the accompanying third-nerve affection. But the outcome is not always so fortunate, for in some cases the paralysis gradually increases during the intervals and ultimately becomes permanent.

Pathology.—The pathology is still obscure. The prevailing and most plausible theory is that the attacks are due to periodical discharges of nerve force originating in the cerebral cortex or in the sensory centres, involving principally the intracranial branches of the trigeminus and the pneumogastric nerves. According to a recent "mechanical" theory, the attack is produced by an acute transient closure of the foramen of Munro and a consecutive swelling of the brain (Spitzer).

Treatment.—Patients with migraine should lead a regular life free from excesses of any kind. The avoidance of mental overwork, and the systematic practice of some form of outdoor exercise are always necessary. All sources of reflex irritation should be investigated. Refractive errors should be corrected by suitable lenses, and if there is any defect in the eye muscles it should be remedied if practicable. This does not necessarily imply that every patient with migraine must be subjected to operation or the wearing of spectacles as a routine method. The same rule holds good in regard to operation for deviation of the nasal septum. While some of these patients are in fairly good health during the intervals between the attacks, many suffer from various manifestations of toxæmia due to gout or rheumatism, such as stiffness and pain in the muscles and joints, vague and fleeting neuralgic pains, etc. The neurasthenic state also requires careful management. Certainly such indications are to be met, and treatment is to be instituted accordingly. Particular attention should be given to the regulation of the action of the bowels and to proper diet. Hydrotherapy is also a valuable adjunct in these cases. The more intelligent patients usually judge from personal experience when the attack is approaching, and in time they also learn to avoid exciting causes. Various drugs have been recommended to abort the attack in its incipiency, or to relieve the pain during the paroxysm, and as a rule they are more effectual the earlier they are administered. Among these may be mentioned ℞ Caffeine, gr. ij.; Phenacetin, gr. x., with or without potassium bromide, gr. xv. ℞ Acetanilid, gr. ij.; Caffeine, gr. ij., to be repeated in twenty or thirty minutes if necessary; or ℞ Codeine, gr. $\frac{1}{4}$; Acetanilid, Caffeine, āā gr. ij. At times a brisk cathartic, such as two or three ounces of Rubinat water, or a few ounces of a strong infusion of coffee, or a moderate dose of wine, whiskey, or champagne will abort the attack, if taken early. If the paroxysm is very severe the pain will generally be relieved by the hypodermatic injection of morphine, or morphine or codeine may be given by the mouth if nausea and vomiting are absent. Some patients obtain relief from applications, to the head, of hot-water cloths or a hot-water bag, while others prefer the ice bag. This is purely a matter of individual susceptibility. A mustard plaster over the nucha, or over the side of the neck in the course of the pneumogastric nerve, also at times diminishes the pain. The use of arsenious acid and extract of cannabis indica administered for a prolonged period of time, has proved that they are most serviceable drugs. ℞ Ext. cannabis indicæ, gr. $\frac{1}{6}$; Acid. arsenios., Strych. sulph., āā gr. $\frac{1}{30}$; Quinin. sulph., gr. $\frac{1}{2}$; Extr. taraxaci, q. s. M. ft. pil. No. i. These pills, given after meals for one week—the dose of the various ingredients being gradually increased each week—should be taken regularly for many months or a year.

When the attacks are frequent and severe, the administration of potassium bromide gr. xv., and fluid extract of ergot ♏ xv. t.i.d. proves serviceable during the first few weeks of treatment.

ORGANIC HEADACHE.

Headache is commonly a pronounced symptom in all inflammatory processes which affect the exterior or interior of the skull. It thus occurs in disease of the periosteum, in caries of the petrous portion of the temporal bone, in inflammation in the cavities situated in the skull, as the frontal and sphenoidal sinuses, the orbital cavity and the middle ear, and in diseases of the brain and meninges. Headache as it occurs in the following conditions will be briefly described: 1. Intracranial tumor. 2. Cerebral abscess. 3. Leptomeningitis. 4. Pachymeningitis. 5. Intracranial syphilis. 6. Vascular disease. 7. Encephalitis. 8. Mastoid disease and sinus thrombosis. 9. Disease of the cranial bones. 10. Diseases of the frontal sinus. 11. Caries of the cervical vertebræ. 12. Acromegaly. 13. Spinal-cord disease.

1. INTRACRANIAL TUMOR.—The most persistent and distressing form of headache is that which occurs in patients with intracranial tumor. It is one of the most constant and obtrusive symptoms. In exceptional instances, headache may be absent during the entire course of the disease. But such a condition is very rare, the headache varying in intensity in different cases. Occasionally it may be of a mild character. As a rule it attains great severity, preventing sleep, and at times becoming so unendurable that the patient has been known to commit suicide. Sometimes the pain is paroxysmal, but more frequently it is almost continuous with periods of great exacerbation. The headache is usually diffuse, but it may be limited to the forehead, parietal region, or occiput, changing its location from time to time. The seat of the pain in the cranium does not necessarily imply that the growth is subjacent. When the pain is confined to the frontal region it by no means indicates that the frontal lobes are involved, for such pain often occurs in cerebellar tumor. The presence of persistent occipital pain extending to the neck would lead us to assume that the growth is probably situated in the posterior cranial fossa. If the headache is limited to a circumscribed area it most frequently corresponds with the location of the growth which has also involved the underlying meninges. If it be confined to one side of the head, the probability is that the tumor is on the same side. This is not an invariable rule, however. The pain is aggravated by everything that interferes with the cerebral circulation. It is thus made worse by psychical excitement, alcohol, coffee, muscular activity, coughing, straining at stool, sneezing, etc. Headache can be considered only one of the prominent general symptoms of brain tumor, and in itself it is of no value in localization. The other important general symptoms frequently found in association with the headache are vomiting, double optic neuritis (choked disc), and vertigo. Various symptoms indicating the location of the lesion are usually present. It is universally assumed that the headache is produced by irritation of the numerous branches of the trigeminus supplying the dura. The dura may also be stretched and irritated as a result of intracranial press-

ure. If this be true, in the former condition the pain would probably be circumscribed, while in the latter we would expect it to be diffused. Clinical facts, however, cannot always be reconciled with this view.

2. Cerebral Abscess.—In cerebral abscess headache is the earliest and most constant general symptom, just as it is in brain tumor. It is generally of great severity, but often manifests itself as a persistent dull ache, deeply situated, and referred mainly to the seat of the abscess. The development and growth of the abscess are likely to produce paroxysms of headache of the severest type. During the latent stage the pain may be slight and occur only periodically. The attacks may last for from several hours to several days. As in brain tumor, the pain is aggravated by everything that causes mechanical congestion or increases the intracranial circulation. The headache may be general, but is more frequently confined to the same side as the abscess. In otitic abscess it may be strictly circumscribed to the temporal region, the pain being first experienced in the ear, and later radiating over the entire head. Abscess in the cerebellum may begin with frontal headache, but is usually accompanied by pain in the occipital region and neck. In cerebral abscess the headache is generally associated with other symptoms of intracranial pressure, as optic neuritis, vomiting, and slowness of the pulse. As the disease advances, there may be general or localized convulsions, weakness of memory, restlessness, irritability, or mental confusion. Fever is generally present, but often disappears for varying periods, only to return higher than before. Frequently the temperature is normal or subnormal. The commonest cause of abscess in the brain is middle-ear disease. In such cases the temporal lobe or cerebellum is most frequently involved.

3. Inflammation of the Pia or Leptomeningitis.—This is always due to an infective process. The acute form is often purulent, and of the cerebrospinal type. Extremely severe general headache is a persistent, prominent, and obtrusive symptom. It may precede or follow a chill and rise of temperature. There may be vertigo, vomiting, general hyperæsthesia, rigidity of the neck muscles, inequality of the pupils, and, later, mental confusion and coma. In *chronic leptomeningitis* persistent headache is a frequent symptom, but it is not present in every case. Its severity is probably dependent on the extent of the process. It is usually accompanied by signs of intracranial pressure, such as vomiting and optic neuritis. The disease may attack either the convexity or the base of the brain. In the former, the cranial nerves escape, there is more delirium, and there may be unilateral or general convulsions and hemiparesis. In the latter, several or many of the cranial nerves may be involved, and there is more marked rigidity of the post-cervical muscles.

4. Inflammation of the Dura or Pachymeningitis Externa.—The headache is usually circumscribed, and is often accompanied by nausea or vomiting and slight fever. When only one side of the convexity of the brain is involved the pain is confined to the same side. In severe cases the disease may extend to the pia, and it is then often accompanied by typical Jacksonian epileptic attacks and hemiparesis on the opposite side of the body. It is usually the result of traumatism to the skull, of caries of the petrous portion of the temporal bone, as in mastoid disease, of syphilis, and of ethmoidal caries. *Pachymeningitis interna or hæmatoma of the dura* is also accompanied by headache and somewhat similar symptoms. This disease occurs most frequently in old people with chronic alcoholism, syphilis, or dementia.

5. Intracranial Syphilis.—Headache may antedate all other symptoms of intracranial syphilis, especially syphilitic meningitis, for several months or years. As a rule, it is the earliest and most constant symptom, and often occurs in paroxysms, or there are periodical exacerbations in which it becomes intolerable. Very frequently such exacerbations occur toward evening or at night, and thus prevent sleep. At times the attacks are periodical. At the height of the paroxysm the pain often becomes excruciating, while during the intervals it may diminish to a dull aching sensation or entirely disappear. The headache is rarely circumscribed (unless there is disease of the cranial bones), but is usually distributed over the frontal, temporal, or parietal regions, and eventually over the occiput and neck. Extreme tenderness on pressure upon the skull occurs only when the periosteum or bones are involved at the same time. The pathological process affecting the intracranial structures is that of arteritis, gumma, or gummatous meningitis. It is uncommon for all three conditions to exist at the same time. The meningitis is frequently of the type of a meningo-encephalitis, and may be confined either to the convexity or to the base of the brain. In the former, there are more delirium, and disturbance of consciousness, and localized or general epileptic seizures, sometimes followed by hemiparesis or hemiplegia. In the latter, the cranial nerves at the base often become involved, thus producing facial or ocular paralysis, etc. Chronic syphilitic meningitis is generally local, and occurs chiefly in the neighborhood of a gummatous growth. The main features or general symptoms of cerebral syphilis are similar to those of tumor. Thus, in addition to headache, there are vomiting, double optic neuritis, and various paralyses. Mental hebetude, somnolence, or periods of unconsciousness are often characteristic and almost pathognomonic symptoms that occur in association with the persistent headache of intracranial syphilis. In addition, there often are alterations in character, loss of memory, mental dulness, and absence of the pupillary light reflex.

6. Vascular Disease.—Headache due to arterio-sclerosis is essentially the result of circulatory disturbances in the brain and interference with nutrition. (See Cerebral hyperæmia and anæmia.) In syphilitic endarteritis, however, the headache is not due to the arterial changes alone, but to the associated meningitis or gumma. Vascular disease, such as arteritis and sclerotic degeneration, frequently arises in conjunction with chronic renal disease, chronic gout and rheumatism, and old age.

7. Encephalitis.—This is an acute inflammatory affection of the brain. It has recently been well-described by Oppenheim as "acute primary hemorrhagic encephalitis." The headache is very severe, and generally affects the entire head, or the pain may be greater in the occipital region and neck. It is accompanied by vertigo, nausea and vomiting, apathy and general depression. These symptoms are soon followed by somnolence, which rapidly develops into unconsciousness. Later, there may be monoplegia, hemiplegia, and various other signs indicating involvement of special cerebral centres. Recovery is not infrequent. The disease is rare, and generally affects young people between fifteen and thirty years of age. As it most frequently complicates or follows acute influenza, it has also been termed "influenza encephalitis." It is acute in its onset, beginning like many of the acute infectious fevers.

There is another form of encephalitis known as "acute polio-encephalitis superior." After several days of headache, vertigo, and vomiting, mental confusion and delirium take place. At about the same time the eyes become involved in paralysis of ocular muscles, which at times develops into complete ophthalmoplegia. It usually terminates in death in about two weeks. Recovery is rare. This disease was originally described by Wernicke. It is an acute hemorrhagic encephalitis confined mainly to the gray matter in the floor of the third ventricle and that of the aqueduct of Sylvius. Chronic alcoholism and infection are the usual causes.

8. Mastoid Disease and Sinus Thrombosis.—Headache occurring in these conditions is usually on the same side as the lesion. Beginning in the ear the pain radiates over the entire side of the head. When severe, it generally arises in consequence of the extension of the infective process to the dura. As the local and general pyæmic infection advances, the headache often diminishes *pari passu* with the obtunding of the sensorium. Furthermore it may be complicated by the presence of a subdural, temporal, or cerebellar abscess, and leptomen-

ingitis may ultimately develop with its usual train of symptoms. Mastoid disease and sinus thrombosis are in nearly all cases due to middle-ear disease and caries of the petrous portion of the temporal bone. Sinus thrombosis is also a complication of facial carbuncle and erysipelas of the head.

9. Disease of the Cranial Bones. Periostitis.—Bone disease affecting the exterior of the skull is the result of traumatism in the majority of instances. In a large proportion of cases, however, there may be periostitis due to syphilis, *i.e.*, periosteal nodes over the cranium. Circumscribed gummata of the skull arise in the most part in the epicranial periosteum. In such cases headache is often constant and, as in all forms of intracranial syphilis, is liable to exacerbations during the night. The bone affected is usually tender and painful to the touch. The headache accompanying cranial periostitis may be mistaken for the form of headache due to muscular rheumatism, or vice versa.

10. Disease of the Frontal Sinus.—In catarrh or suppuration in the frontal sinus, the headache is confined to the frontal region as a rule, but may become general, with the greatest intensity over the affected sinus. At first the pain is dull and intermittent in character. It may gradually or suddenly become persistent and severe and prevent sleep. Percussion over the sinus usually increases the pain. Swelling and tenderness of the tissues over the region of the affected sinus are commonly present, and ultimately all of the symptoms of local and general infection may develop.

11. Caries of the Cervical Vertebræ.—Occipital headache is commonly present in caries of the upper cervical vertebræ. The pain may extend to the parietal and temporal regions, and is increased by movement and deep pressure over the vertebræ. It is usually accompanied by rigidity of the neck muscles, or the head may be partially fixed in the median line.

12. Acromegaly.—The headache may be localized in the occiput or the frontal region, or be confined to one side of the head. It may be continuous or intermittent, and is often persistent and severe, usually being worse in the morning. It is almost always accompanied by ocular symptoms, such as impairment of central vision or bitemporal hemianopsia, which often terminates in optic atrophy and complete blindness. Acromegaly is a rare disease, and was first described by Pierre Marie of Paris, in 1886. Since that time many cases have been observed in this country and elsewhere. The diagnosis of the cause of the headache can be made only by a recognition of the associated pathognomonic physical signs of the disease, *i.e.*, enlargement of the hands and feet, enlargement of the cranial and facial bones, hypertrophy of the tongue, and of the muscular and connective tissues of the extremities, slow but progressive weakness, and the visual defects as above described.

The headache may continue for years or persist during the progress of the affection, and is supposed to be due to the enlargement of the hypophysis (pituitary body).

13. Spinal-Cord Disease.—Headache cannot be considered a symptom of spinal-cord disease. When it is present, it is merely a coincidental element in the general constitutional disturbance, or due to some complication. The characteristic tabetic neuralgic pains occasionally attack the scalp, and are due either to involvement of the spinal or cerebral sensory root of the trigeminus, or to irritation in its peripheral distribution.

General Diagnosis.—The diagnosis of the cause of headache depends entirely upon the patient's history and the presence or absence of certain associated symptoms. This will be readily appreciated after a review of the conditions in which headache occurs, either as a concomitant or as a pathognomonic symptom. The general health of the patient must always be carefully investigated, particularly with regard to the function of the digestive tract and the action of the kidneys. While the seat of the pain is often suggestive, too much stress must not be placed on this indication, for in all forms of headache the pain may vary in its location from time to time. In supraorbital and occipital neuralgia, the pain is more or less paroxysmal and superficial in character, being usually confined to the anatomical distribution of the nerve, and is therefore not a true cephalalgia. Continuous headache lasting many days, with nocturnal exacerbations, should always lead to the suspicion of cerebral syphilis. It is always necessary to decide whether the headache is due to a functional disturbance, or is the result of organic intracranial disease. A safe rule to follow in all cases of persistent headache is to ascertain if any signs of cerebral disease are present, such as muscular spasm; paresis or paralysis affecting the face, extremities, or cranial nerves. A constant general headache which is accompanied by optic neuritis and frequent attacks of vomiting invariably points to intracranial disease. The examination of the pupils should never be omitted. In hyperæmic forms of headache the pupils are usually contracted, while in anæmia they are found dilated. When the pupils fail to react to light, or are absolutely rigid, the vision being unaffected, it is highly suggestive of cerebral syphilis or some other form of cerebral degeneration. The ophthalmoscope often proves extremely valuable in diagnosis. Although abnormities of the cerebral circulation may exist without evidence of such disturbance in the retina, the discovery of "choked disc" or optic neuritis, or a high degree of hypermetropia or myopia, will often be the means of determining the cause of the headache. The most important use of the ophthalmoscope in cases of headache is to determine the presence or absence of optic neuritis. While its absence does not exclude organic disease, its presence is presumptive evidence of some form of intracranial disease (basal meningitis, increased brain pressure from cerebral tumor, or the vascular degeneration associated with renal disease).

Treatment.—A careful investigation of the entire organism is essential in every case, the most important element in the treatment of patients with headache being the recognition of the cause, as the pain is oftener dependent upon some underlying constitutional condition than upon organic intracranial disease. The discovery and correct interpretation of such facts should be the principal guide in the adoption of therapeutic measures. In the toxæmic form of headache, as well as in all other forms, it is absolutely necessary that the intestine be kept free from fæcal accumulation, and that the action of the digestive organs be regulated by suitable diet. Headache from constipation is rapidly relieved by a brisk cathartic. All supposedly reflex causes should be rectified, but too much stress must not be laid upon the paramount importance of such disorders, for many patients seem to possess an inherited or inherent predisposition to develop headache upon the slightest provocation. It is generally desirable and universally advocated that any existing error of refraction or eye-muscle defect be corrected. Even when such conditions are discovered and remedied, relief from the headache does not always follow, for several causes may be operative in the same individual. Therefore, before saddling a patient with spectacles for slight refractive errors, or cutting the eye muscles, or operating upon the nose for deviated septum, or replacing a slightly displaced uterus, or suturing a trifling laceration of the cervix, etc., all other probable causes of the headache should be systematically eliminated. Headache due to cerebral congestion may be relieved by the avoidance of all forms of cerebral stimulants and psychical excitement, regulation of the diet, free purgation by calomel and salines, and the administration of bromide of potassium gr. xv., and fluid extract of ergot ♏ xv., every three or four hours. Severe cases require cupping or blistering over the nucha, and local blood-letting or venesection. It would appear from the experiments of Leonard Hill and others upon dogs that the application of ice-bags to the head as a form of treatment has practically no effect upon the cerebral circulation. Hence the time-honored custom of using the ice-coil and ice-bag in cases of meningitis or cerebral congestion is without any scientific evidence as to its action. Its clinical value, however, is still an open question. When the ice-cap is used, it should always be applied to the shaven scalp. In headache from cerebral anæmia, rest in bed with the head low, and special attention to the cause (which is usually general anæmia) are of prime importance. The administration of cardiac tonics, and the use of iron and easily assimilated food, generally prove successful when organic visceral disease is absent. In every form of headache we are often forced to resort to the temporary use of local applications of dry or moist cold or heat, or some form of anodyne or counter-irritant. Antipyrin, acetanilid, phenacetin, caffeine with bromide of potassium, etc., or diffusible stimulants such as aromatic spirits of ammonia, tincture of valerianate of ammonia, etc., often prove serviceable as symptomatic remedies, but their selection must be left to the judgment of the physician. When headache accompanies the infectious or malarial fevers, the reduction of the temperature by hydriatric or other appropriate measures, or the use of quinine, usually proves efficacious. In headache due to cerebral tumor, free catharsis from time to time, the avoidance of cerebral stimulation or of causes known to produce interference with the intracranial circulation, the administration of the drugs above mentioned, or morphine if necessary, constitute the essential features in the medical treatment. The operation of trephining the skull should be resorted to if other methods fail to relieve the pain. This is often followed by decrease in the intracranial pressure and cessation of the headache. When the tumor is accessible to surgical measures, it should be removed as soon as its location is established. It is customary, before operating, to institute a thorough course of antisyphilitic treatment in order to give the patient the benefit of any doubt as to the possible gummatous character of the growth. The subsidence of headache and other general symptoms of cerebral tumor during the administration of mercury and iodide of potassium does not necessarily imply that the neoplasm is syphilitic, for the irritative symptoms of sarcomatous and other processes have been known to undergo retrogression under this plan of treatment. Headache due to syphilis (gumma, meningitis, periostitis) is rapidly relieved by mercury and iodide of potassium. In cerebral abscess, correct localization and immediate surgical operation constitute our only hope.

William M. Leszynsky.

HEAD, WOUNDS OF.*—Certain features in the anatomy of the skull are of great surgical importance when considering the nature and occurrence of wounds of its component bony parts and of injury to the brain. The periosteum of the cranium—called usually the pericranium—is not thick, but is strong and resistant. Except over the sutures and the great foramina, it can be easily stripped off, or even made to glide over the bone; though in the aged its connection with the underlying bone is more firm. It is nourished principally by vessels from the bone. The internal periosteum of the cavity of the cranium is the dura mater, which is thicker and tougher than the pericranium. Concerning the cranial bones themselves, it should be remembered that the diploë exists only during middle life, and is not to be found in the very young or very old. The amount of space which the frontal sinus may occupy should always be borne in mind.

Of great importance are the connections which the veins of the superficial soft parts enjoy with the deep sinuses and the veins of the diploë through the emissoria Santorini. The most important of these anastomoses are: (1) Among the occipital veins, which connect with the lateral sinus through the mastoid foramen; (2) along and around the interparietal suture, especially its posterior extremity, where numerous openings connect with the superior longitudinal sinus; (3) the ophthalmic veins, according to Sesemann's investigations, empty into the cavernous sinus as well as into the facial veins. It will thus be seen that the sinuses of the brain have their overflow outlets, or "waste weirs," in abundance. Nevertheless, this freedom of venous connection enhances materially the danger from pyæmic or thrombotic trouble in case of erysipelas or phlegmon of the external soft parts.

It will be well, at the very outset, to give here the greatest possible prominence to the classical dictum (so often ascribed to Sir Astley Cooper, but really clearly enunciated by Hippocrates): "*No injury to the head is too slight to be despised, nor too severe to be despaired of.*" There is a great temptation to ignore trivial scalp-wounds, to cleanse them insufficiently, or to dress them carelessly. If nothing else teaches the danger of carelessness in these cases, the experience gathered from the sword-duels of German students should be convincing, since each year several deaths are caused by comparatively trivial scalp- or face-wounds.

SUPERFICIAL WOUNDS.—Bruises and contusions need only slight attention besides rest; evaporating lotions, cold applications, or, if the patient is not seen till after swelling and ecchymosis have taken place, then hot applications constitute all that is required. Upon a superficial abrasion some antiseptic should be used. Any ordinary effusion of blood between scalp and bone will be checked, and then reabsorbed, under this treatment. The hair may be cut short or shaved if required; this should be done if the wound has been in any sense severe. If effusion be very great, and apparently unchecked after prolonged trial with simpler measures, then it would be right to make a free incision, turn out the fluid or solid blood, search for bleeding vessels, twist them or tie them with catgut, cleanse thoroughly, wait till all bleeding has stopped, and then neatly approximate the edges of the incision with fine silk or catgut, with the insertion of a few threads of horse-hair or catgut for drainage, and with a firm compress over all. Of course all this should be done under antiseptic precautions, with clean hands and instruments, etc.

Small punctured wounds need only antiseptic occlusion after their freedom from foreign matter has been secured. Small instruments and weapons sometimes make small punctures, yet wound a vessel of some size. Numerous cases of aneurism of terminal vessels have been reported from such causes. From such a wound hemorrhage would be free, while it would be easy to recognize whether an artery or a vein, or both, had been injured. If a vein, pressure would in most cases suffice; this should be made a part of the antiseptic occlusion, being maintained by an elastic bandage or by some mechanical device.

But if an artery be wounded and such pressure be insufficient, it should be included in a deep suture or occluded by acupressure. This might need to be done on either side of the cut, which should then be cleaned and occluded as before. In other cases it might be well to clip off the hair, shave the part, and enlarge the opening so that the bleeding vessel may be caught and secured.

Extensive lacerations or complicated incised wounds are often received, by which large skin flaps are torn up and the periosteum is stripped rudely off, and yet with only temporary concussion or "stunning."

In such cases the attendant should satisfy himself that the bone has received no such injury as may call for operative interference. He should first check hemorrhage, next shave the parts, and then, with sponge and forceps, address himself to removing every particle of dirt and every loose hair. Shreds of tissue whose vitality is doubtful had best be removed. It then remains only to close the wound. If periosteum have been torn and raised, it is best to readapt the torn edges with fine catgut sutures. Then the superficial wound edges are carefully approximated by silk or catgut sutures, continuous or interrupted. At each angle a stitch may be omitted for the escape of serum, or a few catgut threads may be inserted for capillary drainage.

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* Use has been made in this article of a portion of that which appeared in the first edition of this work on "Skull, Fractures of the Base of," by Dr. Thomas H. Russell, of New Haven, Conn. The part thus used is enclosed in quotation marks.

In the dressing of such wounds, gentle compression should be so exerted as to compel approximation of raw surfaces. For small wounds collodion makes a very serviceable application, the parts being first thoroughly dried and dusted with an antiseptic powder. When a moist dressing is used about the scalp or hairy face, the writer usually prefers a glycerin dressing: *i.e.*, some antiseptic in glycerin solution or emulsion, since whatever serum exudes from the wound will be readily taken up, and the dressing cannot dry and so stick to the parts that its removal will be very unpleasant to the patient.

For all dressings about the head, the writer esteems naphthalin very highly, since it seems to be particularly prophylactic against erysipelas; the latter being more common after head injuries than after those of any other part of the body. Should there be any special reason to fear inflammation, as meningitis, an ice-bag may be applied outside the dressing.

Cases occasionally occur in which some part, or nearly the whole, of the scalp has been torn off or torn loose, as by machinery or "scalping." If the patient be seen in time an effort should be made to replace the loose portion. Astonishing successes have been reported in injuries of this nature, and the case must indeed be very severe which does not justify a trial. The general rules given above are sufficient to guide the reparative effort; perfect cleansing, proper antisepsis, accurate approximation, and judicious pressure constituting the important canons of treatment. Should the effort partially succeed or fail, if the loss of substance be not too great, a plastic operation may be attempted: otherwise the bare or raw surface must be kept clean, and healthy granulations stimulated by such dry applications as zinc oxide or boric acid, or compresses soaked in a saturated solution of potassium chlorate. The healing process may be further hastened by Thiersch skin-grafting. No case of this kind, which is not speedily and primarily fatal, need be despaired of.

The soft spots about the head and face possess great reparative and recuperative power, and pieces which have been severed may yet unite by adhesion if properly and quickly reapplied. Thus, by bites and by various accidents, portions of the nose and ears may be nearly or quite detached. Unless the circumstances be very unpropitious the attempt should be made to restore them. Careful cleansing and perfect approximation are here, as elsewhere, essential to success.

Ragged lacerations of the lips and cheeks may sometimes be cleaned and sewed up; at other times it will be best to trim or pare their edges, and then neatly close the wound, this procedure causing less scar or disfigurement.

It may happen that we are called upon to deal with parts which have already become inflamed, or, perhaps, erysipelatous. In such case we should proceed as follows: The hair or beard should be closely removed. If the appearance of the part or the general condition of the patient indicates any septic process, the wound should be opened, its interior freely exposed to examination, and a most painstaking disinfection of its entire surface made. Foul spots or suppurating surfaces should be treated with an eight-per-cent. solution of zinc chloride, new openings made for drainage at the most dependent parts, and, according to circumstances, the edges reunited or the whole left open to close by second intention, putrefying and necrotic tissue being removed with knife, scissors, or curette. Abscesses should be laid freely open and their cavities disinfected. If erysipelas have supervened, the whole scalp may be covered with antiseptic poultices, of which the best is made of common brewers' yeast, to be soon followed by the Credé silver ointment, or one containing two per cent. of guaiacol and ten per cent. of ichthyol. Few surgeons would feel justified in making ice applications in such a case unless cerebral complications were extremely severe. It will of course be remembered, in the light of the vascular connection between the scalp and deeper parts (*vide* above), that all cases of erysipelas of the head are at least serious.

With reference to later results of former injuries in the way of granulating or indolent ulcers, caries, necrosis, etc., there are no indications calling for treatment different from that generally resorted to for similar conditions elsewhere about the body. A healthy ulcer may be covered by skin grafts, or by a plastic operation; an unhealthy one should first be made healthy. All dead or dying bone should be removed with curette or chisel, and its surface allowed either to heal by granulation or to be covered by a plastic operation.

The soft parts about the head and face are, if possible, more vascular than in other parts of the body. This means, on the one hand, that life may be lost by neglect or from ignorance. Thus, within a short time, the writer has seen a drunken man so completely exsanguinated by hemorrhage from a superficial scalp wound only 2 cm. long, that it was with the greatest difficulty and care that he was recalled to life. On the other hand, by virtue of this excessive vascularity, reparative processes go on more rapidly; and, provided that proper precautions have been taken, it is the rule for most extensive solutions of continuity to heal *per primam.*

Superficial gunshot wounds should be treated on general principles. It must be remembered that a bullet may not only pursue a most tortuous track, but may carry in foreign matter. Such a wound should either receive primary antiseptic occlusion, without the slightest exploration or disturbance, or its track must be carefully cleansed and drained, being laid open for this purpose if necessary. After it has been interfered with or explored it differs in nowise from other wounds, so far as indications for treatment are concerned. There is seldom any positive indication for removal of a deeply buried bullet, save the anxiety of the patient, and this of course is a minor consideration.

DEEP WOUNDS WITH INJURIES TO THE BONES.—Like all other wounds, these call at first for hæmostasis, then for perfect cleanliness, with removal of the hair in the neighborhood. This completed, exact exploration should be made. Should it appear that underneath a small external lesion extensive damage is concealed, then by free incision the whole must be exposed to touch, if not to sight. According to the extent of these deeper lesions the superficial wound, as thus extended, should or should not be reunited.

It may happen that one or more pieces of the external table, or of the malar or other bones, may be chipped off or entirely separated from their bony basis, and held only by their connections with the periosteum and soft parts. Not forgetting that they may still be nourished by these connections, it is, on the whole, the safest plan to remove them, leaving if possible the periosteum. But should a prominent process of bone be thus detached from its seat, *e.g.*, a part of the supra-orbital ridge or margin of the orbit, or even the mastoid process (and such cases have been reported), it would only be proper to make every effort to save it. Such a fragment is to be held in place by pressure, by stitches in the periosteum, or by drilling and suturing with catgut or silver wire. Pieces of bone that lie quite loose must unhesitatingly be removed, even if dura mater or brain be thereby exposed.

Hemorrhage from a denuded bone surface, and oozing from a deep wound, may commonly be checked by ice-water or hot water and pressure. A solution of antipyrin (five per cent.) makes a most excellent styptic, while suprarenal extract or "adrenalin" furnishes almost an ideal remedy in this regard. Once checked, the bleeding is not likely to recur after the wound is protected from the air and dressed with suitable compression.

Aside from leaden projectiles, a great variety of foreign bodies may not only injure the cranial bones and those of the face, but parts of them may even become embedded or disappear from sight—as, for example, workmen's pointed tools, knife-blades, bayonet, sword or foil points, arrow-heads, hatchet or tomahawk points, pieces of glass, splinters or chips of wood, etc. The deeper they penetrate the greater the gravity of the case; the greater also the possibility of perforation or depression of the inner table of the skull. Thus fatal injury of the brain is not so rare in connection with a wound of the orbit, and the condyle of the inferior maxilla has been forced through into the cavity of the cranium. By means of a wound in the oropharynx, death, with literally no external injury, has been caused. In all these cases the indications for treatment are general, yet explicit. Obviously, removal of a foreign body is called for in almost every case, and this should be accomplished with the least possible disturbance. The only exception would probably be when it has totally disappeared within the brain substance. If simple traction be insufficient to dislodge it, enlargement of the external wound and instrumental aid must be resorted to. Strong forceps, a pointed elevatorium, the chisel and gouge, the trephine, or even the surgical engine may be called for. Thus the writer has had to resect almost the entire upper jaw to get away a piece of wood which had been deeply driven into the skull as it flew off from a circular saw. The more recent the case the better, as a rule, the results. If a pointed object have penetrated the cranium, it should be removed by traction in the direction of its line of entrance, so that further injury to the brain or its coverings may be avoided. In such a case it would, in many cases, be well to trephine at the site of its entrance into the skull, in order to remove any depressed bone, and smoothly to round off the opening; by means of the free opening thus made hemorrhage can be more easily checked. Bullets have occasionally been more easily removed by making a counter-opening. This is more easy now than a few years ago when the telephone probe and the Röntgen rays were not available.

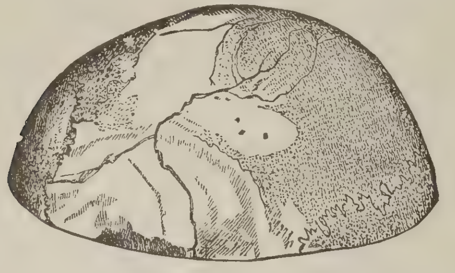

FIG. 2538.—Lines of Fracture Visible on the Outside of a Skull. (After Hewett.)

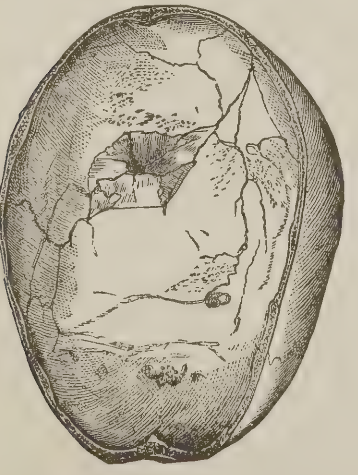

FIG. 2539.—Lines of Fracture Visible on the Inside of the Same Skull. (After Hewett.)

In every case in which solution of continuity of the external table has taken place, the attendant should bear in mind what a vantage ground the diploë offers for the lodgment of septic germs, and for the development of inflammatory and septic thrombotic processes which may greatly militate against the safety of the patient; and he should in such cases omit no precaution which may tend to avert their destructive tendency. Rigid antisepsis, or, if it can be secured, rigid asepsis, must be our motto; without it no such wound can be properly treated.

The possible remote consequences of a blow on the head should not be lost sight of. Inflammatory hypertrophy of the bone may be the result, or caries or necrosis may ensue. These latter may be limited to the part injured, or may be very widespread, affecting one table or both, and even involving the whole vertex. Extensive destruction of the inner table alone has been known, and Saviard's celebrated case proved that the entire vertex might separate, since in his patient, two years after a blow, the whole skull cap came away. Not to speak of other bone lesions, we must also remember the remote results of hemorrhage, as when a clot organizes into a cyst, etc. (*vide Brain, Tumors of*). For every reason, then, we should endeavor to diagnose at the time, if possible, the nature of the injury, and to meet the indication at once, in order that untoward after-consequences may be avoided.

FRACTURES OF THE SKULL.—*General Considerations.*—Those of the vault are usually direct, the result of the force applied, whether the head have been struck, or whether the patient have fallen upon it, and they consist at one time of a depression (in a yielding skull, akin to green-stick fracture), at another of an abrupt perforation, of a linear, a stellate, or a comminuted fracture. Fractures may here, as elsewhere, also be simple or compound. If the fracture be fissured the fissure may be short, or may pursue a long devious line, even to the base of the skull, extending through two or three bones. The comminuted fracture is usually less extensive as far as lines of cleavage are concerned. Fractures of the vertex also involve either one or both of the tables. Thus we often have fracture of the external table alone, and fracture of the inner table without visible lesion of the outer is known. Displacement may occur outward or inward. The lines of fracture visible on the outside of a given skull are seldom any index as to what may be found on its inner surface.

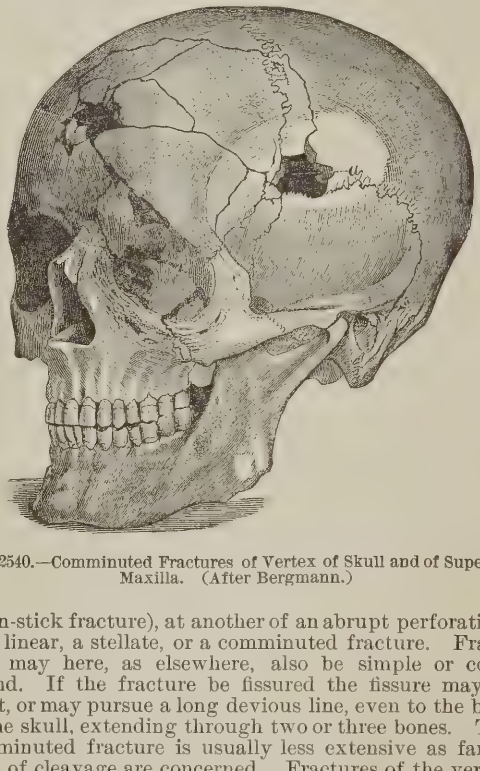

FIG. 2540.—Comminuted Fractures of Vertex of Skull and of Superior Maxilla. (After Bergmann.)

Figs. 2538 and 2539, from Hewett's monograph in Holmes' "Surgery," third edition, illustrate this fact; they represent respectively the outer and inner aspects of a vertex thus injured. A large number of similar illustrations may be found in their appropriate places in the "Surgical History of the Civil War." On the other hand, Fig. 2540, from Bergmann, will give an idea of the extent of some fractures of this kind.

There is, further, the possibility of fracture by *contre-*

coup. By this term is meant fracture by violence transmitted by the arched construction of the skull to a point more or less opposite to that injured. It is known that in cracking a cocoanut, for instance, the shell is not always broken at just the point where the hammer strikes it, but often at some other place. So a blow on the right side of the head may cause fracture of the left side, or in both places. Thus may be explained those cases in which a man sustaining injury, as by a kick of a horse, on the right side, is a little later found to have paralysis of the same side of the body; the explanation being fracture of the left side of the skull by *contre-coup*, with rupture of vessels and formation of a clot (or even rupture of vessels without lesion of the bone), with paralysis consequently on the side opposite the clot as an ordinary compression symptom. There is no limit to the peculiarities of fracture by *contre-coup*, save that it is never depressed.

Concerning the diagnosis of fractures of the vertex, it is not paradoxical to say that it is easy in proportion to the severity of the case, and most difficult when the injury is most trivial. The merest novice may recognize the ordinary compound fracture at a glance, while the expert may be at a loss in some cases of simple linear fissure.

Doubtless many cases of concussion of the brain following head injury are accompanied by some fissuring of one or both tables, yet, while we may suspect this, there is no way of proving it. Even a compound fracture is sometimes overlooked when the broken bone lies deep under the temporal muscle. Mistakes occur in the opposite direction also; thus, mere extravasation of blood has been mistaken for fracture with depression, and pre-existing abnormal depressions have been deemed to be the result of recent violence.

Fractures at the Base of the Skull.

"If we view the skull as a whole from either side, and especially from the rear, it will be noticed that while the upper and posterior surfaces have a dome-like arch the shape of which is well calculated to resist any ordinary violence, the base or under surface, especially viewed from the rear, is nearly flat. This is more strikingly apparent if we make a transverse and vertical section just back of the foramen magnum. This will show that the base of the skull at that point is almost exactly flat, and lacks the arched contour calculated to withstand blows or pressure. This will be made evident by reference to the accompanying illustration (Fig. 2541) of a transverse vertical section just back of the foramen magnum.

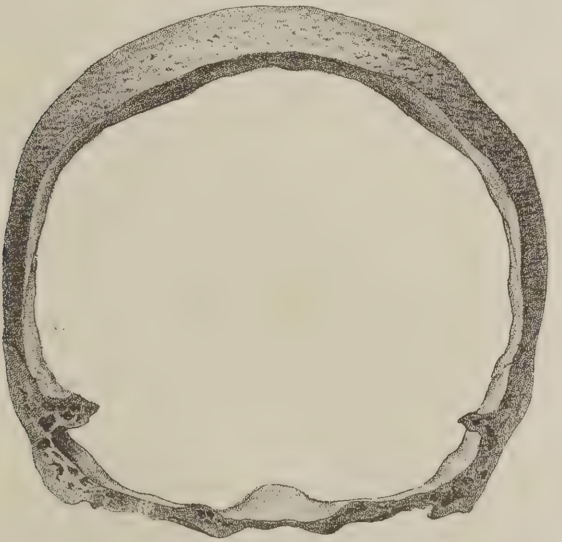

FIG. 2541.—Transverse Vertical Section of Skull through the Foramen Magnum, at Junction of its Middle and Posterior Thirds; showing thinness and flatness of the base in contrast with the thickness and convexity of the vertex. (Thomas H. Russell.)

"A glance at the under surface from without will show that it is weakened, not only by the large foramen magnum, but by the numerous foramina on either side and in front of it. If the base be viewed from within, being held between the observer and a moderately strong light, a considerable portion of the entire base will be found to be quite translucent, and some portions almost transparent, owing to their extreme thinness. The posterior fossa of a skull before me is thinner than at any other portion of its entire contour. In this specimen it is easy to distinguish through the posterior fossa small objects held on the other side of it, the bone here being as thin as the thinnest paper.

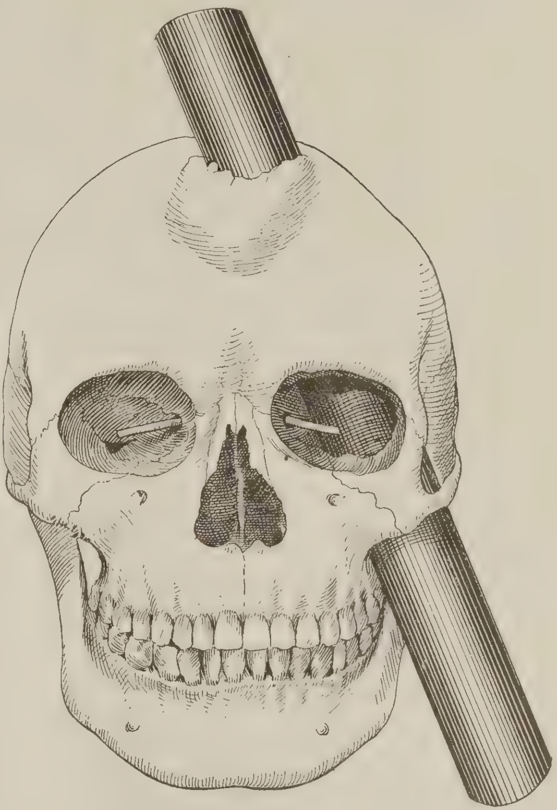

FIG. 2542.—Case Reported by Dr. Bigelow, of an Iron Bar (43 inches long and 1¼ inches in diameter) Driven Upward through the Skull. Recovery.

"While it would appear that the thicker portions of the base—as, for instance, the condyles on either side of the foramen magnum, the mastoid portions of the temporal, the median portion of the sphenoid, and the elevated ridges on the occipital bone—add considerable strength, in reality they do not furnish as much additional support as would at first appear; for if we make sections of these above-mentioned thicker portions, we shall find that they have only an extremely thin layer of outer and inner table or solid bone, and that almost their entire thickness is made up of diploë. They do not nearly compensate for the extreme thinness of the greater portions of all the fossæ and for the numerous foramina. It will therefore appear evident that the base of the skull is relatively weak, and not calculated to withstand more than a moderate amount of violence. The greater portion of the base has little or no diploë. No diploë is to be found in the posterior fossa and in the orbital plates of the frontal bone.

"If it were not for the fact that the base of the skull, from its less exposed position and from its being to a great extent protected from direct violence by being enclosed by the structures of the neck beneath, and for the fact that its great mobility upon the cervical vertebræ lessens the danger from any direct violence, it would be much more frequently fractured.

"The under surface of the brain, that contiguous to the base of the skull, is of greater importance, and any injuries of it are much more serious than those of its upper surface, and it is principally for this reason that fractures of the base are more disastrous than those of the vertex.

"Hilton has drawn attention to the extremely important manner in which the cerebro-spinal fluid protects the base of the brain from injury. He has shown that almost the only part of the base of the brain which is in close apposition with the base of the skull is the inferior portion of the anterior lobes of the cerebrum, where they rest upon the orbital plates of the frontal bone, and that all the other portions of the base of the brain, including those parts most essential to life, do not rest upon the bones at all, nor even touch them, but that under these portions of the brain there is such an abundant accumulation of cerebro-spinal fluid that it forms what he aptly terms a water-bed. No other portions of the brain are thus protected by an abundant supply of cerebro-spinal fluid to break the force of any violence. The contour of the two posterior lobes of the brain does not, therefore, correspond to that of the portions of the skull over which they float on this water-bed.

"The most remarkable case which I have been able to find recorded is described in the *American Journal of the Medical Sciences* for July, 1850, by Dr. Bigelow. A solid bar of iron, three feet seven inches long and one and one-fourth inches in diameter, was driven by a premature explosion of a blast entirely through the skull of a man twenty-five years of age, high into the air, and fell several rods distant. The bar passed upward beneath the zygomatic process on the left side, and through the floor of the anterior fossa of the base of the skull, and emerged near the centre of the frontal bone close to the coronal suture. A considerable portion of brain substance was lost. The patient was almost immediately able to converse rationally, and rode three-quarters of a mile, sitting erect in an oxcart, and after alighting from the cart without aid walked up a long flight of stairs. His recovery was complete in all respects, excepting the loss of sight in the left eye (Fig. 2542).

"Perforations have also occurred in various parts of the base of the skull from gunshot wounds. Wounds from direct violence of this kind are much more common in the anterior fossa than in other portions of the base, its floor being so thin that but little force would be required to thrust any of the above-mentioned foreign bodies through into the brain. Punctured wounds through the anterior portion of the orbit by small slender instruments or weapons leave but very little external evidence of injury. If slender weapons be introduced under the upper lid, nothing is visible but a slight amount of ecchymosis of the conjunctiva. If the wound be external to the lid, there will be nothing visible but the small wound in the region of the eyelid or eyebrow; and as the brain symptoms from such a wound of the anterior portion of the brain may not appear for several days, the gravity of the case or the nature of the injury may be entirely overlooked.

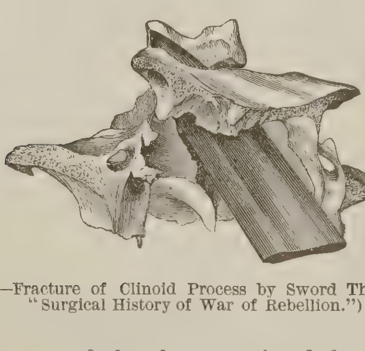

FIG. 2543.—Fracture of Clinoid Process by Sword Thrust. (From "Surgical History of War of Rebellion.")

"Nancrede has called attention to the fact that murderous wounds leaving no trace that can be detected, except upon a very careful examination, could be readily effected by passing a small pointed instrument through the retrotarsal conjunctival fold, and then penetrating the delicate orbital roof and superjacent brain. While this would not be difficult in an adult, it would be especially easy in children.

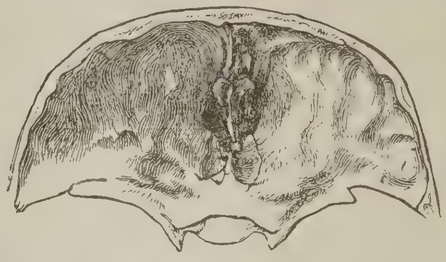

FIG. 2544.—Fracture of Anterior Fossa from a Blow on the Nose. (Bryant.)

"The ethmoid bone has been fractured by a blow upon the nose, driving it upward against the brain.

"The squamous portion of the temporal bone has been fractured by a blow upon the chin, driving the condyle of the lower maxilla through the glenoid fossa.

"It is easy to appreciate how, if a man fall from any considerable height, and especially if, falling upon his head, he strikes upon any soft surface, thus distributing the force of the blow over a considerable area of the vertex, the weight of the body being projected like a blow from a hammer, with the momentum gained by a descent of many feet, against the base of the skull, an extensive fracture of the base might easily be produced. These fractures should be considered as caused by direct violence. As the entire weight of the individual's body, projected from a height of a number of feet, constitutes the fracturing force, it would seem very easy for extensive fissure of the base to occur.

"The above-mentioned fractures, although considered by some as illustrations of *contre-coup*, are the result of direct violence by impact of the base of the skull against the cervical spine, and not properly from *contre-coup*, as formerly considered by Chopart and others, who have recorded their cases of *contre-coup*. Counter-stroke as a factor in the production of fractures of the base probably very rarely occurs, and is much less often referred to in modern medical literature. A fracture by *contre-coup* is one in which the fracture is produced on the side of the head opposite to that on which the blow is received. Grima's definition of *contre-coup* is: 'A lesion produced by a blow in another place than that which received the blow.' The fracture is caused by the violence being transmitted through and around the skull. In a considerable proportion of cases the fracture at the base is a result of the extension of a fissure from a fractured vertex. In those cases in which there is fracture of both vertex and base, the direction of the fracture is from the vertex toward the base. The theory of Aran, who made numerous experimental investigations, was that fractures of the base are always connected with fractures of the vault from which they radiate, following a line within the zone in which the former occurred, and taking a course which corresponds with the shortest route to the base. Aran based his theory upon numerous experiments with dead bodies, and upon old dried skulls.

"Fractures of the base are generally, if not in all cases, only fissured and without marked depression, as in fractures of the vertex.

"SYMPTOMS.—The symptoms are often obscure, and the diagnosis may not be made out with certainty at the outset. Symptoms usually appear early, but may be long delayed, and all may be absent until three or four hours before death, as in a case recorded by Jackson. Hilton mentions an interesting case of a gentleman who was thrown from his horse, striking upon the back of the head, and he was dragged by his foot catching in the stirrup. He subsequently disentangled his foot, mounted his horse again, and rode several miles home. He occupied himself about his usual duties for the following thirteen days, driving, walking, and attending to various business matters, previous to coming under Hilton's care. He then began to suffer from indications of paralysis and subsequently died, and an examination of his skull showed that he had suffered a fracture at the base. Yet during the thirteen days following the injury there was not the slightest evidence of any brain lesion.

"Owing to the location of a fracture of the base, and to the fact that such fractures are only fissured and with little or no depression, it is not possible to make out by inspection or palpation the lines of fractures, as can be done in those of the vertex. The manner in which the violence has been inflicted would guide us very much in our diagnosis, and the symptoms will depend upon the portion of the base which is fractured.

"Hemorrhage from the ears alone is of only moderate importance, for it may occur without fracture, simply from any laceration of the small vessels of the external auditory meatus or the membrana tympani; but if the hemorrhage be prolonged and copious, and especially if it be evidently arterial, as shown by pulsation, and if it be accompanied by other symptoms, or the nature of the accident be such as would be likely to produce fracture of the base, it is a symptom of considerable importance, but is not alone quite conclusive. Severe hemorrhage from the ear has occurred without fracture of the base. This symptom does not occur even in all fractures of the middle fossa, but only when a fracture through the petrous portion of the temporal bone establishes a communication between the injured intracranial vessels and the cavity of the tympanum, the membrana tympani being also ruptured. If, in such cases, the membrana tympani was not ruptured, the blood would escape through the Eustachian tube into the throat.

"Serous discharge from the ear is the most important and almost characteristic symptom of fracture of the base. This discharge is sometimes very copious, so much so that it is recorded that as much as a tumblerful has been discharged in a short time. It has been pretty conclusively proven that this consists of cerebro-spinal fluid, for its composition, whenever examined, has proved to be the same, and there would appear to be no other possible source for such a copious discharge of fluid corresponding in chemical composition. It was at one time erroneously supposed that it was the serum of the blood, or the fluid secreted by the internal ear. The cerebro-spinal fluid is a perfectly clear fluid of a very pale yellow color, and having a specific gravity of about 1.010. It has a saltish taste and its reaction is alkaline. It contains a substance which, according to Foster, although not sugar, acts like dextrose when tested with Fehling's solution. Five cases have been recorded by Wilder (*Medical News*, Philadelphia, 1885, vol. xlvi., pp. 625–627), in which brain substance escaped through one ear. Of these, three were fatal and two recovered. The discharge of cerebro-spinal fluid is possible only when there has been a fracture of the petrous portion of the temporal bone, with rupture of the dura mater and arachnoid, and of the membrana tympani. Cerebro-spinal fluid has rarely been discharged through the nose, when the line of fracture extends through the anterior fossa. In a case recorded by Cameron in *The Lancet* (London, 1884, vol. i., p. 205), there was copious discharge of cerebro-spinal fluid through the nostril and one ear; but the patient, although seventy-five years of age, recovered. Erichsen reports a case (fatal) of a boy who received a wound on the back of the head, with depressed and comminuted fracture of the skull, through the wound in whose scalp a large quantity of cerebro-spinal fluid escaped. This discharge of serous fluid by itself is a very characteristic symptom, and when taken in connection with an accident the nature of which would be likely to produce fracture of the skull, would constitute almost positive proof. A very noteworthy case has, however, been reported by Page (London *Lancet*, 1888, vol. i., p. 774) of a sailor who, after a fall of twenty feet, had ptosis of right eye, partial loss of vision in left eye, and hemorrhage from left ear and nose, followed by copious, clear serous discharge from left ear, and insensibility. Nearly complete recovery soon followed, but he died seven weeks after the accident, and at the autopsy no fracture could be found, but only purulent meningitis. Paralysis of one or several cranial nerves has occurred as a result of fracture of the base. Hemorrhage from the nose and mouth, and subsequent vomiting of blood, may arise in many cases in which there is no fracture. But if the hemorrhage be considerable, and if the nature of the accident were such as was likely to cause a fracture of the base, it may be supposed that the source of the hemorrhage is probably from rupture of an intracranial vessel, the blood escaping from a fracture of the sphenoid or ethmoid bones forming the roof of the nasal fossa. Vomiting of blood in considerable quantity, without hemorrhage from nose and mouth, has occurred from fracture of the base, the blood having been previously swallowed.

"Hemorrhage into the orbit may occur to a very noticeable extent when a fracture implicates the orbital plates, the blood then escaping from the intracranial vessels into the areolar tissue of the orbit, and appearing very noticeably under the ocular or palpebral conjunctiva. The discoloration of the lids from such a cause would not usually make its appearance as promptly after the injury, nor be accompanied by as much swelling, as when due to contusions of the lids from direct violence.

"Loss of vision from hemorrhage into the orbit may occur, as recorded by Rohrbach.

"The only objective evidence of hemorrhage from fracture of the base may be the appearance, after a number of hours, of extravasated blood beneath the skin on the back or side of the neck. In such cases the blood flowing from the broken skull finds its way down along the cellular tissue until it appears beneath the skin, in the neck. Such extravasations beneath the skin are of considerable diagnostic importance, if there has been no direct violence at the location of such extravasations to account for them.

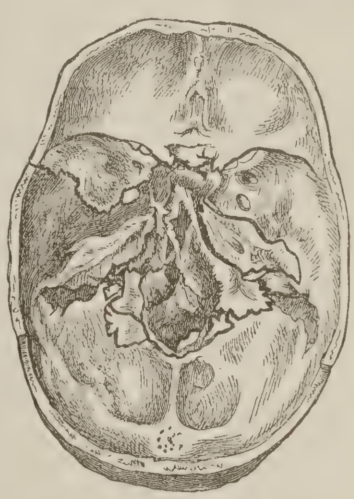
FIG. 2545.—Fracture of the Base by a Fall on the Vertex, which was Fissured. (Erichsen.)

"Vertigo, deafness, otorrhœa, hemiplegia, impairment of vision, and priapism have also been recorded as symptoms. There is no one symptom constantly present in all fractures of the base.

"PROGNOSIS.—Fractures at the base are not as invariably fatal as was formerly supposed. There can be no doubt that recovery occasionally occurs. The prognosis as to the injury of this portion of the skull itself, if there were no accompanying lesion of the brain, would not differ from fractures of other portions, for repair may take place here as in other portions of the cranium. If the patient survived long, union would probably take place, although slowly. According to Hewett, in some cases, even after months and years, no trace of union of the fragments could be found. In others the line of fracture was found partly united by dense fibrous tissue and partly by a thin layer of inlaid bone, while in others bony union was perfect. In some instances of bony union there was an excessive formation of porous bone, it being heaped up along the line of fracture. Usually, however, the injury to the brain results fatally. It is hardly possible for an amount of violence sufficient to produce fracture of the base to fail to produce concussion, laceration, or compression of this, the most delicate part of the brain. As in fractures of other portions of the skull, the prognosis depends almost entirely upon the amount of injury to the brain. Bryant, however, reports a series of thirty cases, with twelve recoveries. In these twelve the injury to the brain consisted of simple concussion."

The importance of a fracture of some part of the skull is subordinate to the importance of the presence or absence of compression symptoms. Along with a simple fracture of the vertex may happen a rupture of some vessel, and the formation of a clot of such size as to determine a fatal ending; on the other hand, we may have a compound comminuted fracture with a minimum of compression or of cerebral disturbance. We need, then, to diagnose the intracranial lesions with greater exactness, if possible, than those of the bone. For the diagnostic signs and symptoms of compression, the reader is referred to the article "*Brain, Compression of*" (Vol. II.). When after injury to the head such evidences of compression are noticed as are there detailed, no matter whether they appear at once, indicating depressed bone, after a few hours, as from a blood clot, or after a few days, as when caused by pus resulting from purulent meningitis, then there is sufficient justification for exploration, and this usually means the employment of the trephine.

After all, in theory at least, it is not difficult to decide on the appropriate course in a given case. In cases of concussion without serious external lesion, we are called on to do but little. If a scalp wound be present, it should be first utilized for purposes of exploration and then closed, as already advised. In cases of contusion of the brain, unless external indications are sufficient, we must pursue a tentative policy. Later, if circumstances call for it, the trephine may be employed. But in cases of distinct compression the trephine is almost always indicated. To be sure, its proper application may call for anatomical knowledge of the construction of the brain of high order; nevertheless, this is no contraindication to operate, it simply calls for expert skill.

American surgeons are now almost a unit on the subject of early trephining, or what may be called the early exploratory use of the trephine. They hold that, inasmuch as the operation is *per se, when properly* (*antiseptically*) *performed*, one of very small danger, we are likely to gain more than we shall lose by employing it for purposes of exploration when in doubt. Personally, the writer thoroughly believes in and advises operation when it seems as if any benefit, either in a diagnostic or in a therapeutic way, may be gained. But before finally deciding on instrumental interference, valuable hints may be gathered from external incision and exploration. The indication for the trephine may be in this way placed beyond the limits of doubt. The writer would then advise, in all but the most plain and typical cases, the following order of procedures in cases of serious injury to the head:

1. Careful external examination and consideration of the general condition of the patient.
2. Exploration with the finger by means of suitable incisions, provided the cerebral condition be other than manifest concussion.
3. Exploratory or therapeutic use of the trephine according to the revelations of the second procedure, or when concussion and contusion symptoms give way to those of compression.

Twenty-five years of experience have impressed upon the writer this lesson: *When in doubt as to the wisdom of trephining, operate.* The case that admits of serious doubt will be safer if operated than without an operation. This is the same rule which I follow in appendicitis; it represents the truest conservatism. Delay in doubtful cases is hazardous, dangerous.

Guided by this aphorism, it would seem as if the practitioner should be much less likely to err than when actuated by the teaching of a certain past era, and of men who are passing away, that the trephine should never be used unless its application seems, even to the novice, plainly and unmistakably necessary.

For the details of the operation the reader is referred to the article under the heading *Trephining*.

WOUNDS OF THE ORBIT.—Those involving the eye or its adnexa are discussed under *Eye, Injuries of;* while those which do not injure the globe are to be treated on the general principles already laid down. We would simply remind the practitioner that, in case of a penetrating wound of the orbit of this character, there is necessity for providing adequate drainage; otherwise pus may infiltrate or burrow into localities where its presence would be most undesirable.

WOUNDS OF INTRACRANIAL VESSELS AND SINUSES.—These most often involve the longitudinal and transverse sinuses and the middle meningeal artery. Wounds of these channels have also occurred during the operation of trephining, and have not been fatal; in fact, in more than one case the effect was rather that of a venesection, and was consequently good. If, by a small punctured wound, a superficial sinus be penetrated, an antiseptic compress may be sufficient to check bleeding; over this an ice-cold application should be made. The cases are numerous in which recovery has followed this simple measure. Death is unusual in such cases, and results rather from other complications, such as injury to the brain, partial escape of blood into the cranial cavity, septic processes, or air embolism. Volkmann has lost a case by entrance of air into a sinus during extirpation of a sarcoma from the bone and dura mater. But under most conditions this would not happen. Wounds of the cavernous sinus through the orbit have always been fatal.

A splinter of bone or a foreign body having perforated a sinus wall, the blood may escape at once or only after its removal. These cases are very rare. Hemorrhage may be checked by antiseptic tampons with ice applications, or the sinus walls may be sewed together with fine catgut or silk, as was first done in one notable case by Dr. C. T. Parkes. Provided they do not prove rapidly fatal, these sinus wounds usually heal well, with only a thickening of walls; but entire obliteration of the channel, should it occur, would be of no great import, as Schellmann's researches have proved. The principal danger comes from softening of thrombi.

Wounds of the middle meningeal artery may be recognized sometimes by the supervention of compression symptoms, even though there be no external lesion indicating them. Among causes of the injury may be mentioned: a direct wound by some sharp object; laceration by projectiles or bone spicula; rupture by changes in relative situation of neighboring bones; rupture without fracture of bones, occurring especially on the side opposite the injury. Rupture having occurred, commotion may retard the formation of clot, but it will form sooner or later. It may even putrefy without visible exposure to the air.

Symptoms of this accident are: An interval of consciousnsess following injury before supervention of somnolence, sopor, and coma—these are sometimes preceded by irritation symptoms, and the compression symptoms may occur at any time after hemorrhage begins, from fifteen minutes up to eleven days; hemiplegia on the side opposite the injury, the artery being right over the motor centres for the opposite arm and leg; changes in the pulse (infrequency and hardness); slow, embarrassed, stertorous respiration; vomiting; loss of reaction to light of the pupil on the same side as the clot; occasional unilateral impairment of sensation; aphasia; disordered bladder and rectum; rise of temperature. If the first four of these symptoms be present, the diagnosis may be regarded as sufficiently accurate to justify operation. The gradual supervention of aphasia indicates extension of the clot anteriorly, disorders of sensation its extension posteriorly, while paralysis of the third pair means that it has extended toward the base of the brain.

Numerous cases of penetrating wounds with lesion of this vessel have been reported. Not infrequently it has required a ligature during removal of fragments after severe injury. During our Civil War the common carotid was seven times ligated for this same purpose, with three recoveries; while now, twenty years later, probably no competent surgeon would hesitate to trephine over its course. A case of Parker's will be instructive in this connection. In this there was no external wound of soft parts; nevertheless he trephined over the artery on one side, but found no lesion; he then trephined over the artery on the other side, but finding no coagulum outside the dura, and noticing that this was discolored and distended, he incised it and removed a considerable amount of blood. In three days the patient became conscious, and afterward quickly recovered.

Symptoms of compression, supervening with varying rapidity, not improbably without external wound, require exploration by means of the trephine, the operation of trephining, with proper antiseptic precautions, being by no means a serious or hazardous one. In trephining with the purpose of finding the artery in question, the point of the instrument should be applied an inch and a fourth to an inch and a half back of the external angle of the orbit; otherwise the instrument should be kept away from this spot. It should be borne in mind that sometimes the vessel lies in a very shallow groove on the under side of the bone, sometimes in a deep groove, and sometimes in a complete bony canal. The instrument must, therefore, be worked with gentleness and care (*vide Trephining*).

If a satisfactory cause of the compression be not discovered on one side, it will be well to take a hint from the case mentioned above, and, remembering the possibility of rupture by *contre-coup* and lesion of the vessel on the other side, to explore there also. Certainly cases of compression are usually desperate enough to justify any search which may reveal the cause and permit its removal.

Wounds of vessels in the brain call for treatment only when diagnosed, and the circumstances which permit diagnosis will also at once indicate the proper thing to do. Could hemorrhage in the subdural space be diagnosed, it would be good practice to trephine, open the dura, and wash out the extravasated blood. One such case was reported during our Civil War (Gross: *Am. Jour. Med. Sci.*, July, 1873).

Injuries to the cerebral portion of the internal carotid are much rarer than those to the meningeal. Longmore relates how a bullet penetrated, in one case, through the orbit into the petrous bone and lodged there, leading later to erosion of this vessel and fatal hemorrhage. Some injury of this kind might, if not rapidly fatal, lead to the formation of an arterio-venous aneurism, calling for ligation of the common trunk.

WOUNDS OF CRANIAL NERVES.—The treatment of injuries to these nerves cannot be other than symptomatic. Should a depressed fragment or a foreign body press upon a nerve trunk, removal of the same would meet the principal indication, and, provided the injury were not too severe in other respects, the nerve might regain some or all of its function. Sometimes, after bruising or contusion of a terminal branch, *e.g.*, the infraorbital, there will ensue so violent a neuralgia as to call for section or exsection of the nerve on the proximal side of the injury. If it be certain that a nerve trunk outside the cranium has been severed, and if the locality of the lesion be reasonably accessible, it would be good practice to cut down upon it and unite the severed ends with a fine catgut suture.

WOUNDS OF BRAIN SUBSTANCE.—Since these are by necessity complicated by those of external parts, we can draw no abrupt therapeutical distinctions. Obviously, if antiseptic measures are indicated for more superficial injuries, they are vitally essential here. The majority of these wounds are inflicted by firearms, and we wish here to emphasize what is elsewhere in this HANDBOOK detailed, viz., the futility—nay, even the homicidal effect—of careless or ineffectual probing for bullets. From time to time in current literature the writer has denounced this practice as vigorously as he could. The array of cases set forth by German military surgeons, in which most dangerous wounds—such as, when treated by old methods of promiscuous bullet-hunting, were surely fatal—primarily and antiseptically occluded, and never probed nor investigated, have gone on to speedy recovery; this array should be most convincing as to the merits of this practice.

Gunshot wounds of the cranial cavity virtually always call for the trephine; but with elevation of depressed bone, attention to bleeding, and smoothing off the edges of the bone wound, the indications are fairly met in the majority of cases. Blood clot is always to be removed, and the source of the hemorrhage attended to; a discolored, pouting dura may justify incision and exploration; while in the effort to remove pieces of bone which have been detached and driven into the brain, the bullet may be found and also removed. But the idea of introducing a probe into the brain through a small penetrating wound of the skull is one which must be abhorrent to every modern surgeon. Random exploration of the brain is never justifiable, and the circumstances which would seem to call for the introduction of the probe through its bony roof would call much more loudly for the use of the trephine. Moreover, many recorded cases prove with what apparent freedom from serious consequences patients may recover with such foreign bodies as bullets in their brains. When circumstances seem to call for a hunt for the missile it may be located with the Roentgen rays, or with the telephonic probe of Girdner, or its equivalent signaling instrument, and when so located it may perhaps be removed by an appropriately planned and perfected operation, done deliberately with every facility at hand, but not otherwise. The safest rule, then, to follow is to *abstain from all operative measures for the removal of missiles when indications are obscure, or such as do not to promise a compensating advantage.*

TRAUMATIC ABSCESS OF THE BRAIN.—By this term is meant abscess formation supervening on injury, as distinct from those cases in which the cause of the abscess is uncertain or unknown. Such traumatic abscesses are more likely to result from gunshot injury than from any other, though they may follow a simple contused wound of the exterior. The symptoms of cerebral abscess, often much resembling those of compression, have already been considered (*vide Brain, Abscess of*). We wish here only to put in a plea, not only for the exploratory use of the trephine when there is good reason to suspect abscess, but of the aspirating needle as well. Should the presence of pus be thus revealed the aspirator should be disengaged, and the needle used as a guide or director upon which to pass a small knife, perhaps a tenotome, and by thus making a freer opening, not only permit escape of pus, but the introduction of a drainage tube and careful washing out of the cavity.

This operative procedure, though bold and radical, is not half so dangerous as to permit the abscess to take its own course, and will fully justify itself.

HERNIA OR PROLAPSUS CEREBRI.—When from a recent wound, or one of a few days' standing, protrusion of brain substance takes place, it may seem doubtful whether it would be better to excise the protruding mass or to endeavor to repress it by suitable pressure. Of course, the careful practitioner will dress all fresh cases with such a judicious amount of pressure as shall guard against this condition; nevertheless, he may be called on to treat it after it has occurred. If the hernial mass has begun to slough there can be no question; excision by ligature, elastic or otherwise, or by the knife, must be practised, and hemorrhage carefully watched for and checked. When the mass is small and appears healthy, gentle and continuous pressure, as by an elastic outside bandage, will usually coax back into the cranium that which belongs there. After complete reduction a lead or caoutchouc plate may be adapted to the shape of the part and applied externally as a part of the bandage technique.

An abscess may underlie the hernial mass; this is to be discovered and treated as above.

Adams has reported a case of irreducible hernia cerebri, in which he succeeded in covering the hernial mass with a flap of skin by a plastic operation, and Kusmin has reported another case, similar to it in many respects, excepting that he resorted to skin-grafting.

Purulent Meningitis.—When compression symptoms supervene several days after injury, there is frequently good reason to suspect the presence of pus. This may be in the form of a circumscribed collection, *i.e.*, an *abscess*, which has already been spoken of, or it may mean purulent or suppurative meningitis. This accession of compression symptoms always, or nearly always, justifies the exploratory use of the trephine. Should it prove to mean compression from suppurative meningitis, there is no reason why the arachnoid cavity should not be washed out, but every reason why it should. In other words, it should be treated just as purulent peritonitis is now treated, that is, by washing out and draining the cavity. Recovery will not always follow this procedure, but it will in a fair proportion of cases, which are inevitably doomed if some such measure be not instituted.

Irritative Lesions following Head Injuries.—These are mostly to be grouped under two classes, viz., convulsive (epileptic) and mental disturbances (mania, dementia, etc.). This hardly seems the appropriate place in which to discuss these at length, the pathological lesions being so varied, including depression of the skull, cystic formations, abscess, etc. Nevertheless there is each year a stronger tendency, on the part of advanced surgeons, to explore these cases when any external scar or depression may indicate rudely a point of attack. The element of risk is small, the prospect of at least alleviation sufficiently hopeful, in conjunction with the otherwise hopeless nature of the case, to justify the attempt, and besides, the degree of success attending these efforts is affording more and more encouragement. In cases of this general nature the exact condition is yet, in individual instances, too uncertain to permit of more than general operative directions. Those which have not already been given in this article can be found in their appropriate places elsewhere in these volumes. This paragraph has been made, therefore, suggestive rather than explicit.

Wounds of the Head during Birth.—With reference to injuries to the fœtal head during artificial or natural delivery, it is necessary to add but little. Even large extravasations of blood are usually absorbed; in extreme cases, after waiting a few days, it might be well to incise, turn out the clot, and sew up the edges of the wound. Excoriations and bruises made by instruments need only conventional treatment. Fatal phlegmonous inflammation has been known to result from injury done by forceps; hence the advisability of antiseptic precautions and attention to detail. Symptoms and appearances arising from compression caused by the forceps will commonly subside as the head resumes its shape. Should positive fracture take place, it will probably run its course uninfluenced by therapeutic measures. No hesitation should be felt about surgical intervention in these cases, when otherwise indicated, simply because of the tender age of the infant or child. The prognosis must be based on the amount of injury.

Roswell Park.

HEALING SPRINGS, ALA.—Healing Springs, Washington County, Alabama.

Post-Office.—Healing Springs. Numerous Cottages.

Access.—Buy ticket to Buckatunna, Miss., on the Mobile and Ohio Railroad, seventy miles north of Mobile; then take hack to springs, fourteen miles east. These springs were discovered in 1870, and have since attained considerable prominence as a health resort. The surface of the country about the springs is broken by high ridges and slopes, and covered by the long-leaved yellow pine. The soil is sandy, and the location has an elevation of about 400 feet above tide water. Like all resorts in this latitude, the winters are mild, the temperature seldom dropping below freezing point. The summers are not exceptionally hot, the mercury almost always sinking to 68° or 70° F. at night. During the recent summer the highest temperature observed was 92° F. The springs are eleven in number, but only four are much used. The "Creek" Spring boils up in the centre of a small stream and flows about eight gallons per minute. It is said to contain lithia, iron, and a trace of arsenic. "Mound" Spring, yielding thirteen and a half gallons per minute, issues from a small mound five or six feet higher than the ground around it. Iron, magnesia, lithia, and sulphur are said to be among its ingredients. "McCarty" Spring, supplying seven gallons per minute, is supposed to contain an acid of some kind and also iron. Its waters are used extensively for chronic diarrhœa. "Scholes" Spring contains iron and sulphur. Many varieties of skin affections, chronic renal diseases, and disorders of the bladder, alimentary tract, and liver are said to receive benefit from the waters of the Healing Springs.

James K. Crook.

HEALING SPRINGS, VA.—See *Hot Springs, Va.*

HEALTH RESORTS.—A change of climate and environment is one of the most valuable means we possess for the treatment or prevention of disease, and this is also to a large extent true in the thorough use of such climate as exists wherever the patient happens to be,—the home climate. To obtain the maximum benefit from any climate, however, one must live in it, *i.e.*, out of doors; hence the beneficial results from an indifferent climate rigorously utilized may be, and perhaps most frequently are, better than those from a much superior climate only partly made use of. An illustration of this statement is found in the results obtained in those sanitoria for pulmonary tuberculosis which are situated in ordinary temperate climates like Falkenstein, or Rutland, Mass., such results being more favorable than those obtained in open resorts with more advantageous climatic conditions. The use of the health resort should be regarded as a therapeutic measure to be as carefully considered and watched as the administration of a drug. Many climates like many drugs are, and must be, empirically used. We can only try them and await the effect. Asthma is a striking example of this use. Why one climate avails and another not we cannot always say, and we can refer the effect only to individual idiosyncrasy, or to some subtle undiscoverable influence in the resort, or to the morbid state of the patient.

Ease and rapidity of accomplishment are always alluring factors in any undertaking. It is easier to take drugs and keep on in the same accustomed way of life than to make the sacrifice which a change of climate so often entails. Hence the inestimable value of climatic therapeutics remains so largely unappreciated and unused, even by the profession. And, further, there is the obstacle, often insurmountable, of the expense involved in a change of climate. Hygiene, dietetics, hydrotherapeutics, and climate are, and always will be, the principal agents in producing cure or amelioration in a large proportion of diseases, and drugs, after all, are only aids in better applying or restoring to their legitimate place these great natural bulwarks of health.

When a physician advises a change of climate he means that his patient should take up a temporary residence in some place known as a health resort and supposed to possess climatic conditions more favorable for the disease of which his patient is suffering than the climate where he is. Intelligently to prescribe a health resort, then, one must consider: first, the classification of climates and their geographical distribution; second, the value of the various climatic factors and their influence upon the human organism; third, the adaptability of special climates to the treatment of special diseases; fourth, the qualifications other than those of a purely climatological character which should be possessed by a health resort. Various classifications of climate have been made by different authors. Weber's appears to be the simplest. He makes two general divisions: *marine* and *inland* climates.

Under the former Solly makes the subdivisions of ocean, island, and coast climates; and under the latter, of low, medium, and high climates. The ocean climate is obtained by means of sea voyages—such, for instance, as the one to San Francisco, viâ the Isthmus of Panama, or to the Mediterranean, or from England to the Cape of Good Hope or to Australia, or, best of all, when possible, a yachting trip which can be prolonged at pleasure.

The ocean climate is characterized by purity of atmosphere, moisture, and equability of temperature; the impregnation of the air with salt, iodine, and bromine may also be of value. Of course many of the weather characteristics depend upon the latitude in which the voyage is taken. Such a climate is a sedative to the nervous system and a stimulant to the appetite and digestion; it is a *sedative tonic*. A sea voyage is applicable to some forms of tuberculous disease, mental exhaustion from overwork, insomnia, various forms of scrofulous disease, anæmia, and chlorosis.

The climate of small islands sufficiently removed from the mainland is much like that of the ocean, modified more or less by currents and by the configuration of the coast. Bermuda, Block Island, the Isles of Shoals are good examples of island climate.

Coast climates resemble that of the ocean, modified by the land influence. Here we have the land as well as the sea breezes, causing less equability and less constant purity of air. A coast climate is also influenced by the configuration and character of the adjacent land. For example, the Alps influence the climate of the Riviera, giving rise to the cold winds which sweep down upon the coast; the desert influences the character of the climate upon the African coast; the inland desert the littoral of Australia. The Undercliff at Ventnor, by its shelter from land influences, is rendered a more purely marine climate.

Weber also divides marine climates into *humid marine* and marine with *moderate* or *slight humidity*. Moreover, for health-resort purposes, such climates as fall under the above subdivision, and at the same time are warm, are chiefly to be considered.

Of the humid marine warm climates, Madeira, the Canaries, the West Indies, the peninsula of Florida are examples. Such climates exercise a sedative effect upon the nervous system and mucous membranes, and are useful in chronic bronchitis with emphysema, bronchial catarrh, and pulmonary congestion in elderly people without cardiac complications. Of the warm marine climates with moderate or slight humidity, we have the Riviera, the coast resorts of southern California, southeastern Georgia, and Solly also includes Florida under this head. The effect and uses of such climates are practically the same as those of the previous class. All the seacoast resorts of the North may be classed under *cool* marine climates with moderate humidity.

Of the inland climates we have first the low ones, such as Egypt, Pau in France, Lakewood, the interior health resorts in the Southern States, the low plains of Arizona, portions of Texas, and the inland resorts of southern California, such as Riverside and Redlands.

Such climates are also susceptible of classification according to temperature and humidity. Their uses as health resorts are very varied; pulmonary tuberculosis, bronchitis, cardiac and renal disease, gout, rheumatism, are some of the diseases likely to be benefited by a low, dry, warm inland climate.

Medium and high altitude climates can be considered together as the difference is only one of degree. Solly makes the distinction depend upon the amount of altitude; from 4,500 feet up he calls elevated climate. Not alone does the elevation influence the character of the climate, but the latitude, the proximity to the ocean and to mountain ranges, and the configuration of the surrounding country; thus Estes Park in Colorado is comparable with Davos in Switzerland, although the former is 1,000 or more feet higher than the latter. The general climatic characteristics of the mountain health resorts are: a rarefied atmosphere, aseptic air, increased diathermancy, dryness, abundant sunshine, and a comparatively low temperature. The chief peculiarity is the lessened barometric pressure, and upon this feature probably depends a large part of the value of such a climate in the treatment of pulmonary tuberculosis. The purity of the air of high altitudes has been compared to that of the ocean and of the desert.

High-altitude climates are found in all the four quarters of the globe: the Alps in Europe; the Andes in South America; the Himalayas in Asia; the Rocky Mountains in North America; the lofty plateaux of Mexico; and the high altitudes of Australia and South Africa. Davos, St. Moritz, Arosa, and Leysen are examples of high-altitude health resorts in Europe; while Les Avants, Goerbersdorf, St. Blasien, and many others in the Black Forest, Harz Mountains, and Alpine foothills are illustrations of mountain resorts of moderate elevation.

The elevated resorts of the Rocky Mountains, from 5,000 to 7,000 feet, have a dryer climate and more sunshine than those of Europe. The principal resorts are found in Colorado, New Mexico, Arizona, Utah, and Texas. Many which are climatically valuable are unavailable on account of the absence of suitable accommodations.

In Colorado we have Colorado Springs, Denver, Estes Park, Glenwood Springs, and others; in New Mexico, Santa Fé, Albuquerque, Las Cruces (3,800 feet) and Silver City; in Arizona, Prescott, Phœnix (1,100 feet), and Tucson (2,400 feet); in Utah, Salt Lake City; in Texas, El Paso. There are also many resorts of lesser elevation in the Adirondacks, Alleghenies, Appalachian and White Mountains, such as Saranac, Asheville, Bethlehem, Kane, and Mount Pocono. In Mexico we have the City of Mexico, Guadalajara, Aguæ Calientes, Toluca, all over 5,000 feet high, and many others. In South America we have the region upon the Pacific slopes of the Andes, many years ago made known as favorable for phthisis by Dr. Archibald Smith. The elevation varies from 8,000 to 12,000 feet, and the chief climatic characteristics are: (1) Moderate warmth; (2) equability of temperature; (3) abundant sunshine; and (4) moderate dryness. There may be mentioned Jauja, Bogota, Quito, Arequipa, and Huancayo.

"Unfortunately," says Weber, "at none of the resorts is the accommodation good enough for invalids."

In India, Darjiling (8,200 feet), Simla, Landour, Naini Tal, and Murree are some of the best spoken-of stations. According to Weber, the testimony of Indian medical officers appears to be rather against the use of the Himalayas in the treatment of lung diseases "and apparently this is on account of the heavy rainfall." In South Africa, Kimberley, Bloemfontein, and Pretoria, all 4,000 feet high or over, are some of the places used as health resorts. "The accommodations for invalids," remarks Williams, "are not up to the European standard," but the climate, he says, has yielded excellent results in his hands.

In Australia, there is the highland region embracing the slopes of the Australian Alps, with an elevation of from 2,000 to 7,000 feet, but only Mount Macedon in Victoria (2,500 feet) and Mount Victoria, New South Wales (3,490 feet) offer satisfactory accommodations to invalids.

There is also the Darling Downs in Queensland (2,000 feet).

To consider now briefly the value of the various climatic factors and their influence upon the human organism:

Temperature.—Extremes of temperature, unless more or less neutralized by some modifying influence like the greater diathermancy of the air in altitudes or extreme dryness, are incompatible with a genuine health resort. That a normally well man can endure great extremes of heat or cold with impunity for a limited season we know, but for very many invalids a moderately warm or cool temperature is to be desired, with a moderate variability. Extreme or rapid changes of temperature are dangerous.

Humidity.—In the majority of health resorts a dry or moderately dry air is desirable. Moist air renders the cold more intense, and the heat more oppressive; moist heat debilitates, favors decomposition, retards evaporation from the skin and lungs. Moist cold increases the functional activity of the kidneys and predisposes to the catarrhal affections of the respiratory and genitourinary tracts.

When judging of the dryness or moisture of the air of a resort, the relative humidity is generally taken as a guide, but it must always be considered in connection with the temperature; and, in order to make a fair comparison, some standard temperature should be taken. 55° F. is given by Wendt as the mean annual temperature of the United States, and this can be taken as the standard.

Assuming this standard, we can, according to Solly ("Medical Climatology," p. 34), make the generalization that 50 per cent. or less relative humidity is dry; 65 to 75 per cent. is medium; 75 to 85 per cent. is moist, and any above very moist. The dew-point and evaporation are also to be taken into account in considering the humidity.

Rainfall.—"It is generally assumed," says Weber (Allbutt's "System of Medicine," vol. i., p. 252), "that considerable rainfall is an injurious condition, but this is not always correct. Provided time enough be left for the invalid to take exercise and sit in the open air, rain is to some degree useful, as it has a purifying influence upon the atmosphere. The notion that *snow* is injurious is even more incorrect." This is especially true when it remains on the ground without melting for a long time, as at Davos, for example.

Whether or not a given amount of the rainfall is a disadvantage is also to be considered in connection with the character of the soil; if the latter is porous, quickly absorbing moisture, the amount of rainfall is of less importance than if the soil is clayey and holds the water.

Wind.—Winds vary in their effects according to the temperature, humidity, purity, and velocity of the air in motion. They often produce great and sudden changes which are always undesirable for an invalid. Cold, damp winds are never good, and cold or hot dry winds, like the Mistral of the Riviera or the Föhn of Switzerland, are too irritating or debilitating.

The direction of the wind is also an important factor in its influence upon the invalid, for from one direction it comes fresh and pure, blowing over forest expanses or from the hills, while from another it may come laden with dust and germs, exhausted of its ozone and deficient in oxygen. From another direction they "bring with them, so to speak, the climates of distant regions."

Beside their direct action upon the human organism, winds are great ventilators and purifiers of the atmosphere.

Light and Sunshine.—A large amount of sunlight is requisite for a good health resort; it cheers the mind, has a stimulant and tonic effect upon the nervous system, probably favors tissue metabolism, and destroys various bacteria, notably the tubercle bacillus. A cool, dry air and sunshine such as is met with in the high altitudes, is a combination of striking value for the tuberculous patient.

The influence of light and sunshine upon the naked body is probably far more potent for good than we realize. The reader is referred to two interesting papers upon this subject by Dr. William Duffield Robinson in the Transactions of the American Climatological Association for the years 1898 and 1899.

In considering any health resort, then, the average number of clear, fair, and cloudy days is to be especially noted. Outdoor life is what is desired, and without a large amount of good weather this is seriously interfered with.

Atmospheric Pressure.—The physiological effects of a diminution in atmospheric density has been fully considered in the article upon "*Altitudes, High,*" and the reader is referred to it for a discussion of this subject.

Electricity.—What effects atmospheric electricity produces upon the human organism is not sufficiently understood to enable one to make any definite statement regarding it. This much we know, that the presence of a large amount of electricity in the atmosphere, as in elevated regions, appears to enhance the favorable influence of a climate.

The configuration of the land often modifies the climate of a health resort, for better or for worse; a hill or mountain range may afford protection from high winds or those blowing from an injurious quarter; or if the resort is in a valley the daily amount of sunshine may be reduced, as at Davos. Moderate ascents are often of value for exercise, as Brehmer utilizes them at Görbersdorf for his consumptives, or as they are used in the Oertel "cure de terrain."

Vegetation is an important factor to consider in the selection of a health resort. The existence and character of the vegetation not infrequently modify materially some of the purely climatic factors. Forests render the climate more equable, lead to increased rainfall, and have a higher relative humidity. The fir, pine, spruce, and other evergreen trees are generally considered beneficial to a health resort on account of their balsamic exudations, their shade, and soothing effect. Lakewood, Summerville, and Aiken are illustrations of resorts among the pines; the Adirondacks, and many portions of the White Mountains, of resorts among the fir and spruce.

"The covering of the soil with vegetation," says Williams ("Aero-Therapeutics," 1894), "protects it from the sun's direct rays, and the temperature of plants exposed to the sun does not rise so high as the soil itself, because much of the heat is lost through the large evaporation which takes place from the leaves and stems, and which gives rise to air currents tending to reduce the temperature. The result is that the heat is more evenly distributed over the twenty-four hours, and is less intense in the hottest time of the day." A knowledge of plant life is desirable on account of its bearing upon hay fever.

The character of the soil of a health resort is an important fact to know; dryness of soil and subsoil is obviously of advantage. Dampness favors disease, especially phthisis. The condition of the soil influences the temperature and moisture of the lower zone of air by the quantity of moisture it absorbs, the rate at which evaporation takes place, its porousness, capacity for warmth, and rapidity with which the ground is heated or cooled.

The sandy soil of the desert, for example, has great power of accumulating heat, and equal power at night of radiating it and producing a great lowering of temperature; hence the great range of temperature during the twenty-four hours.

There are other essential qualifications than those of a purely climatic character which should be possessed by a health resort. For example, it is important for the invalid to know what facilities exist for comfortable living, without which the best of climatic conditions are likely to prove elusive. Pure drinking water, good sanitary arrangements and sewerage, proper accommodations as to ventilation and heating, food of proper quality and properly cooked, efficient attendants, and facilities for an outdoor life, especially if the open-air "Liege Kur" is to be taken, are all matters of the first importance for the success of the health-resort cure. There should exist an intelligent and active board of health, the members of which should supervise not only the general sanitary condition of the resort, but the hotels, boarding-houses, or rented cottages where consumptives have resided; and they should see to it that after such residence renovation and disinfection are satisfactorily performed, as, for example, is done at Cannes (*vide* article on *Cannes* in the HANDBOOK). Facilities for out-of-door exercise, amusement, and mental occupation are important features of a health resort. Is there a library? Are there schools? What are the churches?

Ease of accessibility is often a strong point in favor of a resort; and equally important is it to know the method of reaching the place selected, the expense of the journey and of residence there. No resort should be chosen for a genuine invalid which does not contain one or more good physicians known either by reputation or personally to the physician who sends the patient away; and the latter should be referred to the local physician by a letter from the home physician, briefly stating the case. Honest statistics of cases treated at health resorts are perhaps the most valuable indications of the actual benefits to be expected from a residence at the resort for whatever disease its climate is supposed to be especially curative.

The establishment of good sanatoria under careful, expert medical supervision, especially for pulmonary tuberculosis, is greatly to be desired in such health regions as Colorado, New Mexico, the pine belt of the South and elsewhere. Some few already exist, such as Trudeau's at Saranac, the Loomis Sanatorium at Liberty, and others. For many invalids a well-conducted hotel or boarding-house, and a competent local practitioner in the neighborhood answer well.

A practice which is not unusual, but which is to be strongly deprecated, is for the home physician to attempt to retain the guidance of his patient while at the health resort. The local physician of necessity must be better acquainted with the local hygiene, the local risks, and all the local conditions, so important for the invalid to be made aware of in order to obtain the best results from the climate of the resort.

Regarding the adaptability of certain climates to the treatment of special diseases, only a few general indications will be given here, and the reader is referred to the articles upon the various health resorts in the HANDBOOK for a more detailed consideration of this portion of the subject.

For phthisis, for which a health resort is sought more frequently than for any other disease, the essential climatic conditions, as has been more than once before stated in this HANDBOOK, are pure air free from dust, protection from high winds, moderate dryness and equability, and a dry soil. Such a combination of conditions is not hard to find nor does one have to travel far to obtain it. With it, however, must be associated, as has so often been insisted upon, the most careful, continuous, medical supervision; hence the great value of sanatoria.

It must also ever be borne in mind that the stage of the disease, its activity, and the general condition of the patient are always to be carefully considered in deciding upon a resort, or if any change is advisable.

Assuming that the patient is in the incipient, curable stage, and that there are no other contraindicating conditions, the writer would arrange the favorable climates in the following order of excellence: (*a*) High altitudes, like Colorado, New Mexico, the Alps; (*b*) low altitudes, like the Adirondacks, Asheville, the Southern pine belt, and southern California; (*c*) coast climates, represented by the Riviera resorts; (*d*) island climates, like Madeira and the Canaries; (*e*) ocean voyages. As to results, according to Solly ("Medical Climatology," p. 141), the high altitudes are the best, the sanatoria the next, and the lowland climates come third.

Bronchitis.—When expectoration is abundant, a dry, warm, inland climate like Thomasville, Augusta, Summerville, and Camden, S. C., southern California, in the winter; and the seaside or mountains in the summer. If the expectoration is scanty, a warm moist climate like Florida, Nassau, Algiers, Madeira, in winter; and Newport, the Jersey coast, Nantucket, Cape Cod, etc., in the summer.

Pleurisy.—In the convalescent stage when recovery is delayed, or the lung does not expand—the higher altitudes, provided the condition of the heart permits. Likewise in retarded pneumonia, in individuals under thirty-five years of age, and when the heart is normal, and the lungs are not too seriously involved, Solly recommends the higher altitudes, under proper restrictions.

Asthma (*Bronchial*).—Although the climatic treatment of this complex disease is largely a matter of trial, yet the high-altitude resorts appear to give the best results, especially when the neurotic element seems to be the prominent factor in the case. If the bronchitis, the determining cause, seems to be the most important element, either a sedative or a stimulant climate is to be selected according to the character of the bronchitis. Or if the exciting cause appears to be the most important, especial consideration must be given to that in the selection of a resort.

Hay Fever (*Nasal Asthma*).—The Adirondacks, White, Catskill, and Allegheny Mountains, Mackinac Island, Georgian Bay, Cape Breton, the "North Woods," Beach Haven, Fire Island, and Halifax, Nova Scotia, are some of the many resorts which afford more or less immunity. An ocean voyage and travelling in Europe are also prophylactic.

Tuberculous Glands.—Seaside resorts, sea voyages, and high altitudes. The seaside preferably, with salt baths.

Rheumatism.—Warmth, dryness, equability, and sunshine are essential factors in the climatic treatment of rheumatism; such conditions are found in Texas, Arizona, the Southern Pine Belt, some portions of southern California, the inland Florida resorts, the desert of Egypt, and Algeria.

It is also to be remembered that the hydrotherapeutic treatment of this disease as exhibited at such resorts as Richfield Springs, the Virginia Hot Springs, the Arkansas Hot Springs, Aix-les-Bains, and others, is most efficacious.

Renal Disease.—A warm, equable, windless climate, such as is found in many low inland or coast resorts, examples of which are Arizona, Madeira, the Southern Pine Belt, Florida, southern California, etc. The West Indies are highly extolled by Burney Yeo.

Cardiac Affections. — Warmth, equability, sunshine, and in some cases moderate elevation. "With regard to the heart and great vessels," says Solly ("Hare's System of Practical Therapeutics"), "it may be stated as a generality that they are much more apt to be improved on the sea than on the mountains."

Chronic Diseases of the Genito-Urinary Organs.—Warm and moderately dry climates. Renal tuberculosis requires in general the same climate as pulmonary tuberculosis.

Nervous Maladies.—Each disease must receive its own especial consideration in regard to climate. Some, perhaps the most, require a mild, low climate; others a mildly stimulating one.

Neurasthenia.—Any climate which affords rest, a change of scene and diet, with life in the open air, such as a life in the woods, at sea, or on the plains, is likely to be beneficial. Solly is of the opinion that the larger proportion of cases of neurasthenia are most surely and quickly benefited by high climates, when no especial contraindications exist. When any one symptom is predominant, a climate which is favorable to that is to be selected. If it is insomnia, for instance, the climate which best relieves that—sometimes high altitudes, sometimes the low resorts or the seashore—will prove most beneficial to the general condition.

Senility with its Accompanying Changes.—A warm, sunny, equable climate, where the individual can exist comfortably with the least expenditure of vital force; in winter Florida, southern California, the Riviera, many resorts in the Southern States. Whatever the resort selected it is of the first importance that good accommodations and food should be assured.

Convalescence from Acute Diseases—such as typhoid fever, epidemic influenza, whooping-cough, diphtheria, etc. A warm, sunny climate, inland or seashore, where the patient can live out of doors, protected from wind, and can bathe in the sunshine. Atlantic City, Old Point Comfort, Lakewood, are examples.

Many other diseases and conditions are amenable to climatic treatment with more or less success, and in selecting a health resort for them the writer cannot do better than to repeat for the guidance of the practitioner the three principles enunciated in the previous edition of this HANDBOOK by the accomplished author of the articles upon health resorts: "1. A thoughtful, conscientious, and painstaking consideration of the precise pathological condition of the individual patient, and of his constitutional peculiarities. 2. A careful study of the effects produced upon the human organism, both in health and disease, by variations in each and all of the meteorological factors of climate. 3. The detailed study of these factors as they exist in the climate of each place which experience has proved to be, or analogy has led us to regard as likely to be, well suited for use as a health resort"; and, to this may be added the statement with which Solly wisely concludes his article upon "Climate" in "Hare's System of Practical Therapeutics": "In selecting a climate for an invalid let us above all remember to examine not only the suitable application of the climatic factors to the disease, but also into the peculiarities of the individual and his attendant circumstances."

A word in conclusion regarding home climates. It is true with climates as with other things, that familiarity often breeds contempt. In looking for a health resort we too often forget the possibilities of our own home climate. In the treatment of phthisis as well as other diseases we can, not infrequently, obtain surprising results by a painstaking utilization of the favorable climatic conditions existing in the patient's own locality.

A judicious arrangement of rooms and verandas so as to obtain the utmost possible sunshine and out-of-door life, ingenuity in providing shelter from the wind, ample ventilation, and an equal attention to the hygienic-dietetic *régime* which we would give in a health resort, with the same assiduous devotion to getting well, may produce as happy results as those obtained in many well-known health resorts.

Therefore the physician or his patient should not give up hope by any manner of means, if the conditions preclude a change of climate. "I can cure consumption in any climate," said Dettweiler. *Edward O. Otis.*

HEALTH, STATE BOARDS OF*.—The recognition of the necessity of general or central boards of health or sanitary organizations in each of the States may be said to date from the middle of the nineteenth century. A resolve of the Massachusetts Legislature of 1849 authorized the governor to appoint a commission whose duty it was to make a sanitary survey of the State and to report upon the same. This extremely thorough and comprehensive document presented a plan of organization for a general or state board of health, and although it was nearly twenty years before such a board was organized, the plan laid down in that report was very closely followed in the act of 1869 which authorized the establishment of a state board of health.

The first three state boards of health were organized in three widely separated States, Louisiana,† Massachusetts, and California, in the order named, and these were followed by the establishment of similar general boards in Virginia, Minnesota, and Michigan. The States and Territories which have thus far established state boards of health, with the dates of their organization, are given in the following list:

Louisiana, 1855.
Massachusetts, June, 1869.
California, March, 1870.
Virginia, February, 1872.
Minnesota, March, 1872.
Michigan, 1873.
Maryland, April, 1874.
Alabama, January, 1875.
Georgia, June, 1875.
Colorado, February, 1876.
Wisconsin, March, 1876.
Mississippi, February, 1877.
New Jersey, March, 1877.
Tennessee, March, 1877.
Illinois, May, 1877.
Connecticut, January, 1878.
Kentucky, March, 1878.
Rhode Island, April, 1878.
South Carolina, December, 1878.
Delaware, 1879.
North Carolina, 1879.
Iowa, March, 1880.
New York, May, 1880.
Arkansas, March, 1881.
Indiana, March, 1881.
West Virginia, March, 1881.
New Hampshire, August, 1881.
Missouri, March, 1883.
Maine, February, 1885.
Kansas, March, 1885.
Pennsylvania, June, 1885.
Ohio, April, 1886.
Vermont, November, 1886.
Florida, February, 1889.
North Dakota, 1889.
Nebraska, March, 1891.
Washington, March, 1891.
Oklahoma, March, 1891.
South Dakota, March, 1891.
Nevada, March, 1893.
New Mexico, February, 1895.
Utah, February, 1898.

In general, it may be said that the work of state boards of health has not been largely of an executive character, but has been eminently didactic, and much good has been accomplished by the publication and distribution of tracts, circulars, and pamphlets, relating to the various departments of sanitary work, and by the holding of frequent conventions or assemblies for the free discussion of sanitary subjects.

As a general rule, state boards do not have authority over local boards in sanitary matters, but in some instances they are authorized to exercise co-ordinate power with local boards in preventing the spread of infectious diseases, either within the limits of municipalities or along the border of other States and countries.

The most important duty of sanitary authorities is the management and control of infectious diseases, and while the state boards of health are, from their essential composition, not so closely in touch with the people as municipal boards, yet they are capable of doing excellent service in educating the people in this important sanitary question. In those States which are the most densely settled, and are of comparatively small area, it has been possible for the general boards to perform a considerable amount of executive work, and to carry out the provisions of such laws as have given them authority to act for the protection of the public health.

In several of the States, notably those of the western part of the Union, the function of regulating the practice of medicine has been added to the more distincive duties of public sanitation.

A valuable summary of the powers and duties of state boards of health as they existed in 1879 may be found in Dr. Billings' Introduction to the volumes on "Hygiene" published in New York by Dr. A. H. Buck. In this summary Dr. Billings says: "The state board of health should be the central supervising authority, having much the same relation to local boards that the local board has to the households. Its functions may be classed as follows: (1) To promote the organization of local and municipal boards; (2) to obtain medical and vital statistics; (3) to investigate the causes of undue sickness and mortality; (4) the removal of these causes, acting as far as possible through the local sanitary authorities; (5) the supervision of the hygiene of state institutions; (6) the supervision of quarantine."

ANNUAL PER CAPITA EXPENDITURE OF STATE BOARDS OF HEALTH IN THE YEAR 1898.

(Population Estimated to 1898.)

Groups.	States and Territories.	Fraction of dollar.	Groups.	States and Territories.	Fraction of dollar.
Over 2 cents	Florida	.0866	Less than 2 mills	West Virginia .	.0017
	Vermont.......	.0301		Missouri	.0016
	Massachusetts .	.0236		Kansas	.0015
1 cent to 2 cents	Rhode Island ..	.0167		Nevada	.0015
	Texas..........	.0144		Kentucky	.0012
	Mississippi	.0141		South Carolina.	.0012—
	Maine	.0112		North Carolina.	.0011
	New Hampshire	.0106		Virginia.......	.0011
	Minnesota	.0105		Pennsylvania..	.0010

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* Condensed from article in "Past and Present Condition of Public Hygiene and State Medicine in the United States," 1900.

† The Louisiana board created in 1855 could hardly be classed as a state board of health, though so named in its organic act, since it was created almost entirely for the purpose of maintaining a quarantine to protect the city of New Orleans.

ANNUAL PER CAPITA EXPENDITURE OF STATE BOARDS OF HEALTH IN THE YEAR 1898.—*Continued.*

(Population Estimated to 1898.)

Groups.	States and Territories.	Fraction of dollar.	Groups.	States and Territories.	Fraction of dollar.
5 mills to 1 cent	Utah	.0098	Less than 2 mills	South Dakota	.0010—
	Connecticut	.0092		Washington	.0007—
	New Jersey	.0089		Nebraska	.0001
	Delaware	.0070	0	Arizona	.0000
	New Mexico	.0055		Georgia	.0000
	New York	.0052		Idaho	.0000
2 mills to 5 mills.	Maryland	.0049		Montana	.0000
	Colorado	.0042		Oregon	.0000
	North Dakota	.0040		Wyoming	.0000
	Ohio	.0040			
	Louisiana	.0040			
	Arkansas	.0036			
	Michigan	.0035			
	Oklahoma	.0032			
	Tennessee	.0029			
	Wisconsin	.0038			
	California	.0027			
	Iowa	.0023			
	Indiana	.0021 +			
	Illinois	.0021			
	Alabama	.0020			

The preceding table presents the per capita expenditure of each state board of health in 1898, upon an estimated population for that year. The comparatively high expenditure of the Gulf States of Florida, Texas, and Mississippi was employed chiefly for the maintenance of quarantine in preventing the introduction of yellow fever from other States and countries.

Samuel W. Abbott.

HEART.—The heart is a four-chambered hollow muscle, divisible functionally into two parts, each consisting of two chambers, an auricle and a ventricle. The right half of the heart comprises the right auricle which receives the venous blood from the body general through the venæ cavæ, and the right ventricle which receives the blood from the auricle through the auriculo-ventricular orifice, and sends it by the pulmonary artery to the lungs. From the lungs the aërated blood is received by the left auricle through the pulmonary veins, and by it transmitted to the left ventricle through the left auriculo-ventricular orifice, the left ventricle in turn pumping the blood by way of the aorta back again to the body. This pump is supplied with appropriate valves to determine the direction of the blood stream (see *Circulation of the Blood,* Fig. 1328).

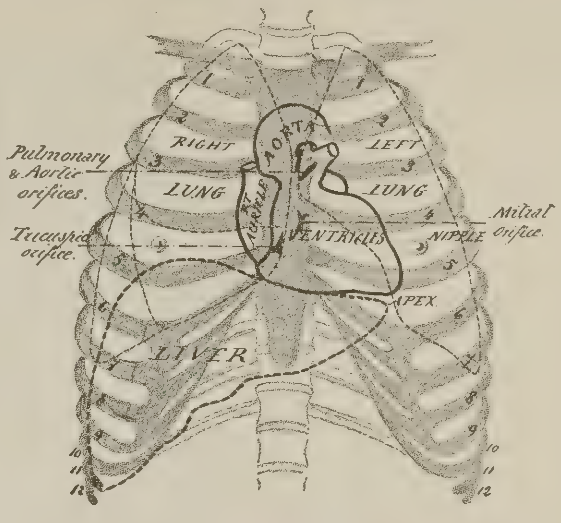

FIG. 2546.—Outline of Heart, Lungs, and Liver to Show their Relations to Each Other and to the Chest Wall. Heusman and Fisher's "Anatomical Outlines."

If the heart be removed from a cadaver that has been preserved by injection with a solution of formalin, which so hardens the tissues that they preserve after removal

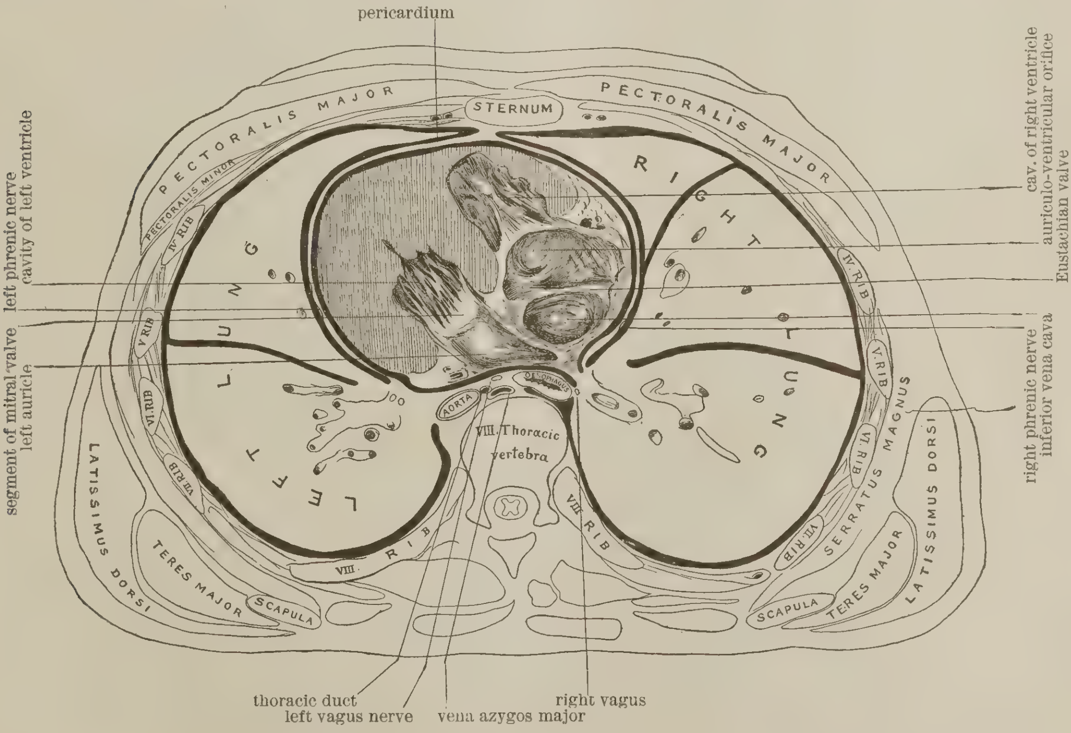

FIG. 2547.—Cross Section of Thorax at Level of Eighth Thoracic Vertebra. (Braune.)

the form they had *in situ,* it is seen to be not so much a conical as a distinctly six-sided organ; the sixth side or upper surface being, however, obscured by the fact that it is almost entirely occupied by the openings of three great vessels, the superior vena cava, aorta, and pulmonary artery (Fig. 2548 and 2553). Two well-marked grooves are distinguishable on the surface of the organ (Figs. 2549 and 2553): the *auriculo-ventricular groove* which marks the separation of the auricles from the ventricles and lodges the main trunks of the cardiac vessels and corresponding nervous plexuses; and the *interventricular groove* seen on the anterior and inferior surfaces of the heart, which marks the separation of the two ventricles and larger branches of the cardiac vessels. A considerable amount of fat in which the vessels are embedded fills up these grooves and obscures them till dissection makes them more prominent. The heart, with the orifices of the vessels that spring from it, occupies a separate serous cavity in the thorax between the two lungs and pleuræ, called the *pericardium,* the heart with its fibro-serous pericardial sac forming the contents of the middle mediastinum (Fig. 2547). Its situation and relations will be readily understood by reference to Figs. 2546 and 2547, the former being self-explanatory, the latter a horizontal section through a frozen body at the level of the eighth thoracic vertebra. Both figures show that the organ is markedly deflected to the left side. Before considering the relations in detail we will make ourselves acquainted with the excised heart. Examined externally the *auricles* are conspicuous by the thinness of their walls, and mainly occupy the right and posterior aspects of the heart. The *ventricles* are thick-walled, form the greater part of its anterior, left and inferior aspects, and the left ventricle is drawn to a blunt point, which is the meeting place of the three just-named surfaces, and is known as the *apex* of the heart.

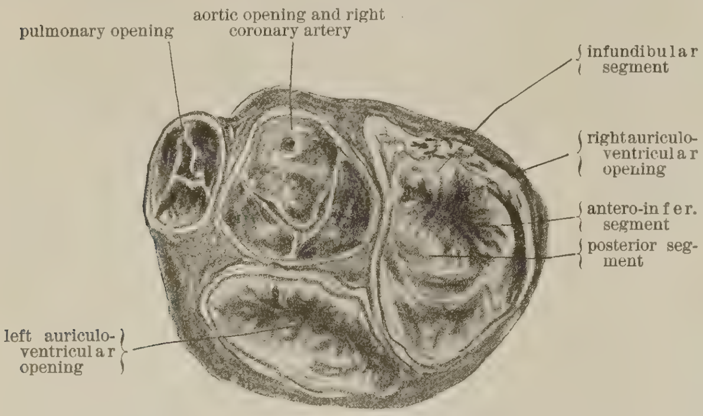
aortic opening and right coronary artery
pulmonary opening
infundibular segment
right auriculo-ventricular opening
antero-infer. segment
posterior segment
left auriculo-ventricular opening

FIG. 2548.—View of Ventricular Orifices, the Auricles and Arteries being Removed Close to the Ventricles. W. Keiller ad naturam del.

The *right auricle* (Figs. 2549, 2550, and 2554) on the surface presents a quadrangular outline, and occupies the whole right and part of the anterior, posterior, inferior, and superior surfaces of the heart. At its posterior inferior angle is the *inferior vena cava;* at its postero-superior angle the *superior vena cava;* while its antero-superior angle is prolonged into an angular diverticulum which extends round in front of the aorta and is called the *auricular appendix.* The anterior limits of the two cavæ are united by a groove on the surface of the auricle called the *sulcus terminalis* (Fig. 2549) which marks off the portion of the auricle formed by union of the two venæ cavæ from that portion which belongs to the primitive auricle. On opening the auricle (Fig. 2550) this latter portion is found to present on its inner surface a large number of branching muscular ridges united by a membrane so thin as to be translucent. Over the right wall of the auricle these ridges are fairly regular and nearly parallel. They extend from a prominent crest, the *crista terminalis* (which corresponds in position to the sulcus terminalis), to the region of the auriculo-ventricular groove and are called *musculi pectinati.* In the appendix they are much branched, and run vertically across its cavity.

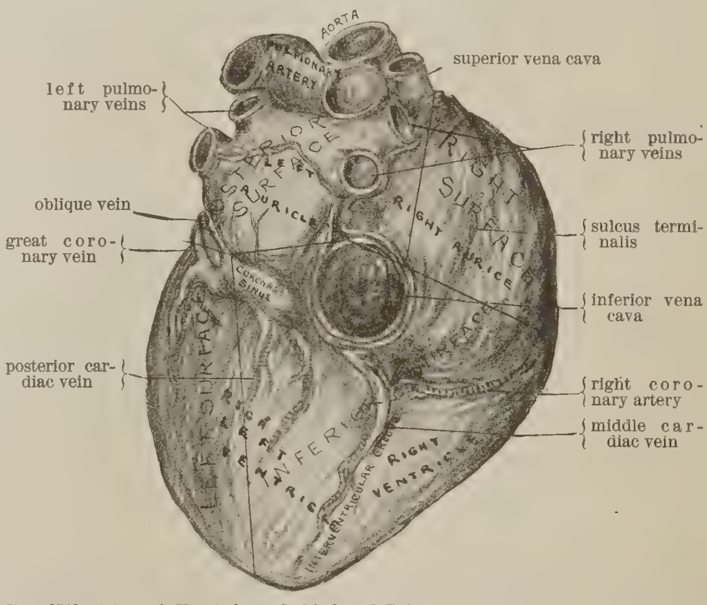

FIG. 2549.—View of Heart from Behind and Below. The surfaces are outlined in black lines. (His, two-thirds.) W. Keiller del.

The rest of the interior of the auricle is smooth and is called the *sinus venosus.* Its left wall in front is in close contact with the commencement of the aorta, and behind this is formed by the septum between the auricles. Here there is a circular depression where the septum is translucent. This is called the *fossa ovalis,* is about five-eighths of an inch in diameter, and is surrounded, except at its lower part, by a prominent muscular ridge, the *annulus ovalis.* The ridge is specially prominent above, and under it is a deep recess, closed after birth except for an occasional minute canal through which a probe can be passed, but open during fœtal life for the free passage of blood from the right to the left auricle. The opening in the fœtal condition is the *foramen ovale.* At the postero-superior angle of the cavity will be found the orifice of the superior vena cava, large enough to admit the little finger, and unguarded by any valve. At the posterior inferior angle is the orifice of the inferior vena cava, which will admit two fingers. Stretching from the right anterior margin of the inferior caval opening to the anterior limb of the annulus ovalis is a prominent musculo-membranous ridge, the *Eustachian valve,* whose function in the fœtus is evidently to guide the blood from the inferior vena cava through the foramen ovale. Its prominence and constancy in the adult seem to show that though its fœtal function is lost, it still serves an important purpose in directing the intra-auricular blood currents. Its muscular portion consists of a strong bundle of fibres which surround the inferior cava and are attached to the septum, thus possibly constricting the caval opening during auricular systole. On the floor of the auricle, just in front and to the left of the inferior caval opening, is the orifice of the *coronary sinus*, guarded below by a delicate semicircular valve which is frequently fenestrated and is called the *valve of Thebesius*. The antero-inferior angle of the right auricle runs into a large funnel-shaped opening, the *auriculo-ventricular orifice*. (Figs. 2548 and 2550). This opening is oval or triangular in shape, readily admits three fingers, and is guarded by the *tricuspid valve*. In addition to these openings there are scattered over the walls of the auricle numerous small pits and little openings called *foramina Thebesii*, some of which are blind depressions, while others are the orifices of small veins.

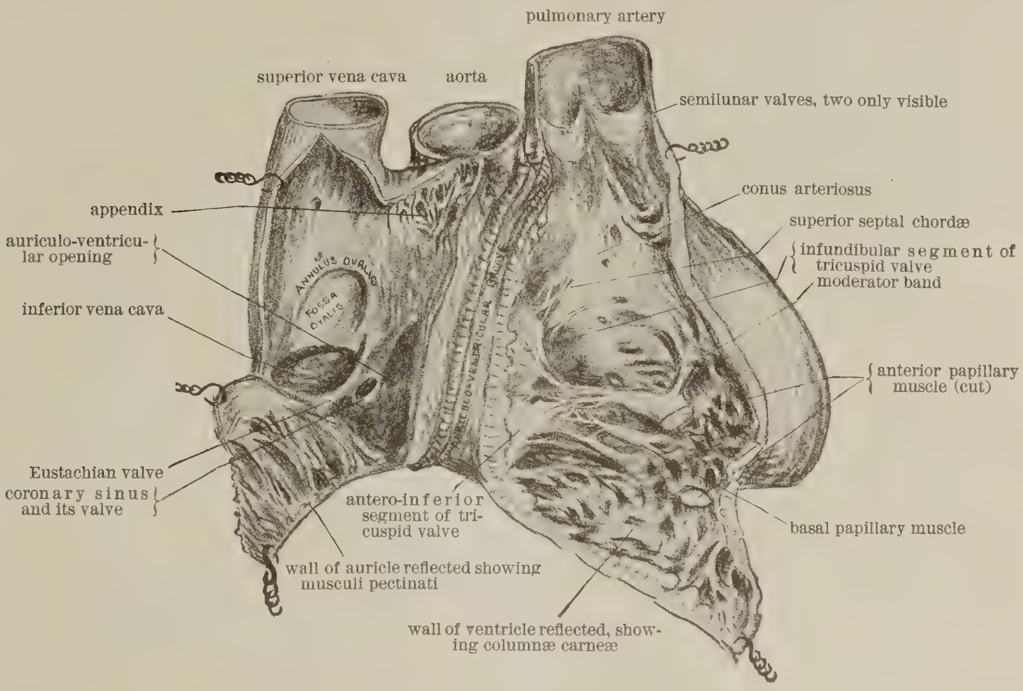
pulmonary artery
superior vena cava
aorta
semilunar valves, two only visible
conus arteriosus
appendix
superior septal chordæ
auriculo-ventricular opening
infundibular segment of tricuspid valve
moderator band
ANNULUS OVALIS
FOSSA OVALIS
AURICULO-VENTRICULAR GROOVE
inferior vena cava
anterior papillary muscle (cut)
Eustachian valve
coronary sinus and its valve
antero-inferior segment of tricuspid valve
basal papillary muscle
wall of auricle reflected showing musculi pectinati
wall of ventricle reflected, showing columnæ carneæ

FIG. 2550.—Right Auricle and Ventricle Opened, Somewhat Stretched Out for Better Display. Drawn from nature by W. Keiller, 1901.

The *right ventricle* (Figs. 2550, 2553, 2557) occupies the greater part of the anterior surface, and about half the inferior surface of the heart. It practically forms the whole anterior inferior border, but stops short of the left inferior angle of the heart, the so-called apex. When opened it is seen to present a floor and three walls, anterior, left, and posterior, the three walls tapering upward to form a smooth funnel, the *conus arteriosus*, which leads into the pulmonary artery. This orifice is guarded by three semilunar flaps which together form the *pulmonary valve*. The left wall of this cavity is convex, owing to the great thickness of the wall of the left ventricle, and here the blending of the walls of the two ventricles forms the interventricular septum (Fig. 2551). The lower two-thirds of the posterior wall of the right ventricle is occupied by the large *auriculo-ventricular* orifice, the upper third tapering into the conus arteriosus and lying in close relation with the aorta. With the exception of the conus arteriosus, the walls of the ventricles are marked by an intricate network of muscular ridges and bands called *columnæ carneæ*, the ridges being mere thickenings of the wall, the bands attached at both extremities and free in the middle. A varying number of these fleshy columns, called *musculi papillares*, end in fibrous string-like bands, the *chordæ tendineæ*, which are attached to the segments of the tricuspid valve. The *tricuspid valve* (Figs. 2548 and 2550), which guards the auriculo-ventricular orifice, is composed of three triangular segments; consisting of fibrous tissue clothed with endocardium, thick at their bases where they are attached around the opening, and thinning off toward their free margins, which are trans-

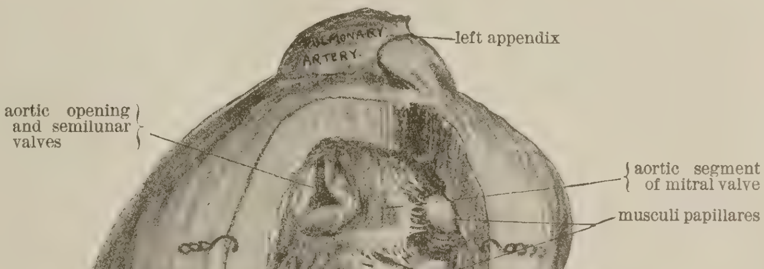
PULMONARY ARTERY.
left appendix
aortic opening and semilunar valves
aortic segment of mitral valve
musculi papillares

FIG. 2551.—View of Opened Left Ventricle, much Foreshortened. W. Keiller ad naturam del.

lucent and jagged. The extent to which the flaps are separated varies greatly, while sometimes there are small intermediate lobes between the main segments. Branched, thread-like chordæ tendineæ pass from the ventricular wall or papillary muscles to the free margins, ventricular surfaces, and attached bases of the segments, each papillary muscle or group of muscles sending cords to the contiguous margins of two separate flaps. Thus when the ventricle contracts the blood is forced in behind the cusps which come together and, being prevented by the chordæ tendineæ from bulging too much into the auricle, effectively prevent reflux of blood into the auricle and compel its flow into the pulmonary artery. Of the three segments the antero-superior is the largest, and separates the conus arteriosus from the auriculo-ventricular orifice. It is therefore called the infundibular segment. It is smooth on both its auricular and infundibular surfaces. The other segments are placed antero-inferiorly and posteriorly, and the last (being in contact with the septum) is called the septal segment. The *musculi papillares* in the right ventricle vary exceedingly. The best marked springs from the anterior wall and has usually a muscular band of varying thickness, called the *moderator band,* attaching its base to the ventricular septum. It sends chordæ to the infundibular and antero-inferior segments. A group of small papillary muscles occupies the floor and lower part of the septum and supplies chordæ to the contiguous margins of the antero-inferior and septal segments; while from the upper part of the septum, in the conus arteriosus, a few chordæ pass directly without a distinct papillary muscle to the contiguous margins of the infundibular and septal segments. The pulmonary valve is so similar to the aortic that one description will do for both.

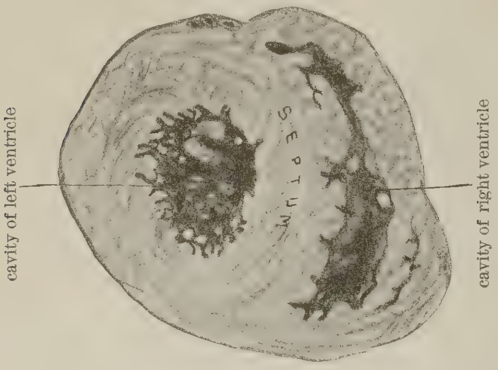

FIG. 2552.—Cross Section of Heart through Ventricles. W. Keiller, ad naturam del.

The *left auricle* (Figs. 2549 and 2556), which occupies the whole posterior surface of the heart, is quadrilateral in outline and slightly convex. At its right and left margins are the openings of the *right and left pulmonary* veins, usually two of each. They vary greatly in size and situation. The *auricular appendix* extends upward and forward from its left superior angle and slightly overlaps the pulmonary artery in front and to the left of that vessel (Fig. 2553). The left auricle is somewhat thicker-walled than the right. On the interior the walls are smooth and the musculi pectinati are few and short and almost entirely confined to a small part of the roof and appendix. The posterior wall and floor are smooth. The left wall is narrow and presents the openings (usually two) of the left pulmonary veins; the right wall has posteriorly usually two, seldom three openings of the right pulmonary veins; none of these has valves. In front of these the right wall is formed by the interauricular septum, and presents superiorly one or two semilunar slits which mark the remains of the foramen ovale. They correspond in position to the upper part of the fossa ovalis and one of these may be still patulous. In five average specimens before me the foramen is not completely closed in any one, but an oblique slit varying from .01 to 1 cm. long occupies its place, and there is no evidence of the last having caused any cardiac embarrassment. The anterior wall in the upper part lies in close relation with the conus arteriosus of the left ventricle and commencement of the aorta; and its lower half is occupied by the obliquely placed somewhat oval *auriculo-ventricular orifice* (Fig. 2548) which admits two fingers easily, thus being distinctly smaller than the corresponding orifice on the right side. It is guarded by the *mitral valve.*

The *left ventricle* (Figs. 2555 and 2551) forms the whole left surface of the heart, a small portion of its anterior, and about half its inferior surfaces. On cross section its outline is seen to be almost circular, its walls being at least twice as thick as those of the right ventricle, which therefore moulds itself to the thicker-walled cavity and assumes a crescentic outline (see Fig. 2552). Its cavity is long and conical, the apex of the cone running to the extremity of the so-called apex of the heart which is thus formed by the left ventricle. The base of this conical cavity presents two orifices (Fig. 2551), the lower of which points backward and opens into the left auricle, and is guarded by the *mitral valve;* while a smooth funnel-like portion runs upward, backward, and to the left into the *aortic opening,* this last being somewhat smaller than the auriculo-ventricular opening, and guarded by the *aortic valve.* The *columnæ carneæ* are short, thin, much branched and best marked at the apex of the conical cavity. The *mitral valve* is composed of two large, well-marked segments, thicker and stronger than those of the tricuspid valve, and between them are two distinct subsidiary flaps. Two large prominent *musculi papillares,* springing respectively from the left and inferior walls of the cavity, send chordæ tendineæ to the upper and lower margins of the valvular segments respectively. They are so situated that when contracted with the ventricular systole they pull the margins of the segments together. Of these two segments, the anterior or *aortic*

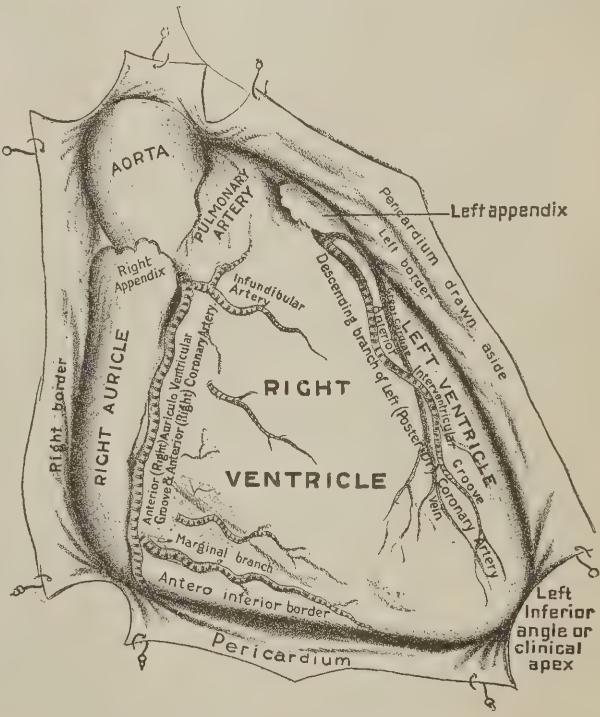

FIG. 2553.—Anterior Surface of the Heart, Pericardium Opened. W. Keiller ad naturam del.

segment separates the auriculo-ventricular from the aortic orifice (Fig. 2551), and is smooth on both its auricular and its ventricular surfaces, the chordæ being attached to its margins only. The *aortic valve* is composed of three semicircular or semilunar folds of fibrous tissue lined below by the endocardium and above by the intima of the aorta. Their convex margins are attached to the ring round the aortic orifice, and their straight edges are free. Thus three pouches are formed open toward the aorta, into which the blood flows when the systole passes off, and thus brings the three segments together so as effectively to stop regurgitation of blood into the ventricle. The aortic wall bulges slightly at each pouch, and each bulging is named a *sinus of Valsalva.* These sinuses in the aorta are arranged, one anteriorly, two posteriorly, and from the anterior sinus springs the *right coronary artery* (Fig. 2548), while the *left coronary artery* springs from the left posterior sinus. Each segment of the valve has at the middle of its free edge a fibrous nodule, the *corpus or nodulus Arantii,* toward which the stronger fibres radiate so as to leave an exceedingly thin, sometimes fenestrated lunated margin on either side of it, called the *lunula.* The free margin of the valve is strengthened by a fibrous band. The portion of the ventricle which leads up to the aortic orifice is so strengthened by fibrous or fibro-cartilaginous tissue as to remain uncollapsed during diastole. The septum between the ventricles is thick and muscular, except for a small area where the aorta springs from the septum. This is the *pars membranacea* of the septum, and here a congenital defect in the septum may cause an abnormal communication between the ventricles.

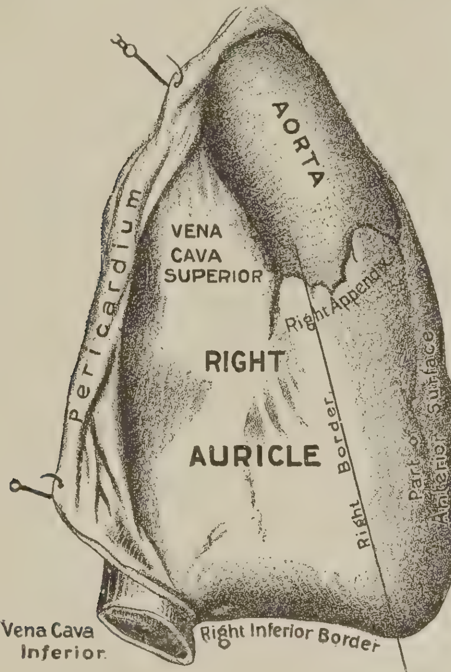

FIG. 2554.—Right Surface of the Heart. W. Keiller ad naturam del.

Relations and Surfaces of the Heart.—As has been already pointed out, the heart is a six-sided or cuboidal body, presenting anterior, right, left, posterior, inferior, and superior surfaces. The *anterior* surface (Fig. 2553) is the first which meets the eye when the thorax is opened. It is triangular in shape, the apex of the triangle being completed by the merging of its upper limit into the aorta and pulmonary artery. It is slightly convex and is directed forward and a little upward, being in sagittal mesial section parallel with the sternum. In it are included the greater part of the right ventricle and portions of the left ventricle, left auricular appendix, right appendix, and part of the right auricle. It is bounded below by the sharp, almost straight *antero-inferior* border (*margo acutus,* inferior border of clinicians), on the right by the nearly vertical and convex *right anterior* border (right border of clinicians), and on the left by the oblique, convex, and slightly rounded *left anterior border* (left border of clinicians). Its left inferior angle forms the *clinical apex. Relations:* Separated from it by the pericardium (Fig. 2547) are the margins of the lungs and pleuræ, sterno-pericardial ligaments, triangularis sterni, internal mammary vessels and sternum, with the fourth, fifth, and sixth left costal cartilages.

The *right surface* (Fig. 2554) is markedly convex, four-sided, lies almost vertically, and is directed toward the right. It is composed of the greater part of the right auricle. Its anterior, posterior, and inferior borders are only slightly rounded and are therefore well defined. At its superior extremity the surface blends with the wall of the vena cava superior and its posterior inferior angle is similarly related to the vena cava inferior. *Relations* (Fig. 2547): It is separated by pericardium from the phrenic nerve and vessels, pleura, and inner surface of right lung.

The *left surface* (Fig. 2555) is a convex triangular area directed mainly upward and toward the left. It includes about one-half of the free surface of the left ventricle and left auricular appendix. It is separated from the anterior surface by the left anterior border; from the inferior surface by a rather sharp left inferior border; and behind it is bounded by the left pulmonary veins and left auriculo-ventricular groove, with the great coronary vein embedded therein. *Relations* (Fig. 2547): It is separated by the pericardium from the left phrenic

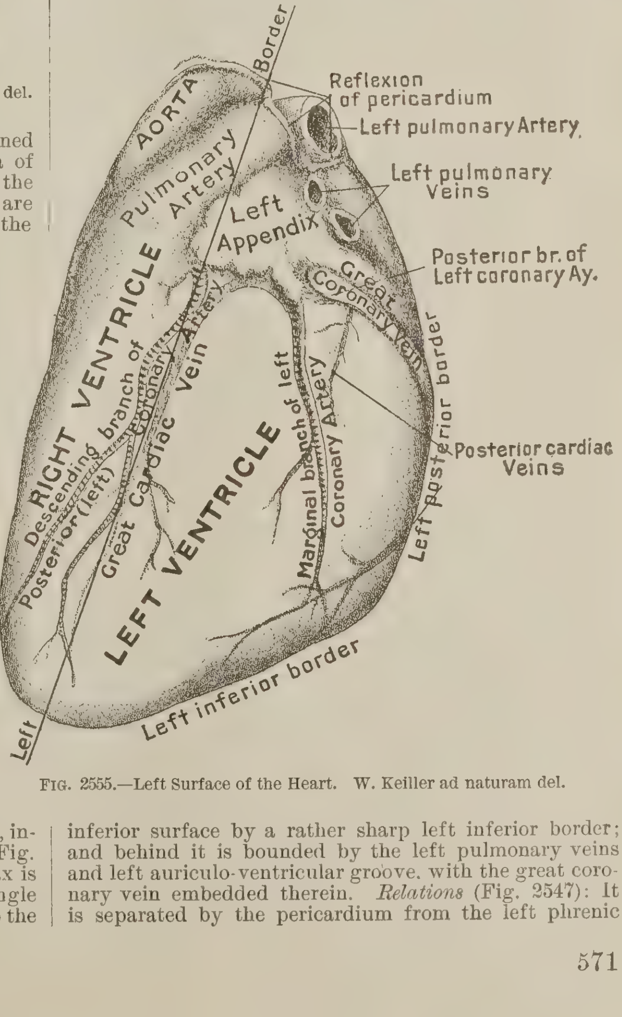

FIG. 2555.—Left Surface of the Heart. W. Keiller ad naturam del.

nerve and vessels, left pleura, and inner surface of left lung.

The *posterior surface* (Fig. 2556) is called the base in text-book descriptions. It is four-sided, convex, vertical, and directed backward. It is formed by the left auricle, and by the portion of the right auricle which joins the two venæ cavæ, and is bounded below by the inferior vena cava and coronary sinus, above by the right pulmonary artery, on the right by a fairly defined border joining the two venæ cavæ, and on the left by the left pulmonary veins and great coronary vein. It is only partially invested by the visceral layer of the pericardium. *Relations* (Fig. 2547): It is separated by pericardium from the bronchi, œsophagus, vagi, descending aorta, vena azygos major and thoracic duct.

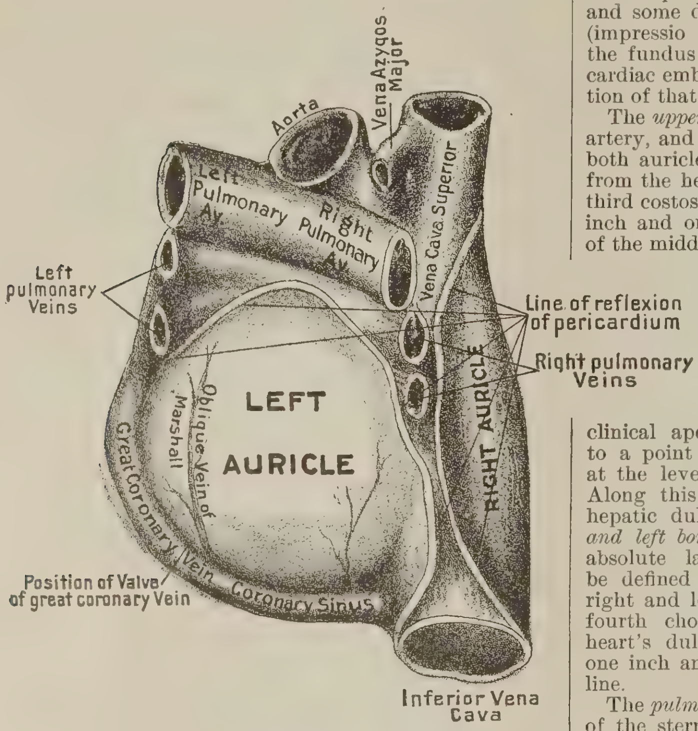

FIG. 2556.—Posterior Surface of the Heart. W. Keiller ad naturam del.

The *inferior, diaphragmatic surface or true base* (Fig. 2557) is quadrilateral, slightly convex when the ventricles are distended or in systole, slightly concave when they are relaxed and empty. It is directed downward and a little backward and toward the right, and is bounded by rather sharp and well-defined borders. It includes a small portion of the right auricle and opening of the inferior vena cava, the rest of the surface being about equally divided between the right and left ventricles. Behind the inferior vena cava is seen a small portion of the left auricle. It presents the inferior extremities of the right and left auriculo-ventricular grooves, and the inferior interventricular groove. *Relations* (Fig. 2546): It is separated by the central tendon of the diaphragm and some diaphragm muscle from the superior surface (impressio cardiaca) of the liver. Its close relation to the fundus of the stomach will help to account for the cardiac embarrassment apt to be caused by acute distention of that viscus.

The *upper surface* gives origin to the aorta, pulmonary artery, and superior vena cava, and is partly formed by both auricles, especially the left. These vessels spring from the heart on a level with the upper margin of the third costosternal articulation, along a line extending one inch and one-half to the left and one inch to the right of the middle line.

Superficial indications (Fig. 2546): The *upper limit* of the heart has just been indicated. The *clinical apex*, or apex beat, is felt between the fifth and sixth ribs, three and a half inches to the left of the middle line. The *antero-inferior border* is indicated on the chest wall by an oblique line, slightly convex downward, extending from the clinical apex on the left, across and slightly upward to a point one inch to the right of the middle line at the level of the sixth chondro-sternal articulation. Along this line the cardiac blends insensibly with the hepatic dulness. These lines being drawn, the *right and left borders* of the heart's anterior surface or the absolute lateral limits of the heart's dulness will be defined by convex lines joining respectively their right and left extremities. Thus, on a level with the fourth chondrosternal articulations, the area of the heart's dulness extends three inches to the left and one inch and three-quarters to the right of the middle line.

The *pulmonary* and *aortic valves* lie behind the left half of the sternum on a level with the lower border of the third costal cartilage. The *right auriculo-ventricular* opening lies behind the sternum on a level with the fourth intercostal space and fifth cartilage. The *left opening* is a little higher and more to the left. (Compare Figs. 2546 and 2548, it being remembered that the surface represented in Fig. 2548 lies obliquely so as to point very decidedly toward the right).

In children the heart is relatively broader and projects more to the left than in the adult, and the apex beat may be in line with the nipple or external to it.

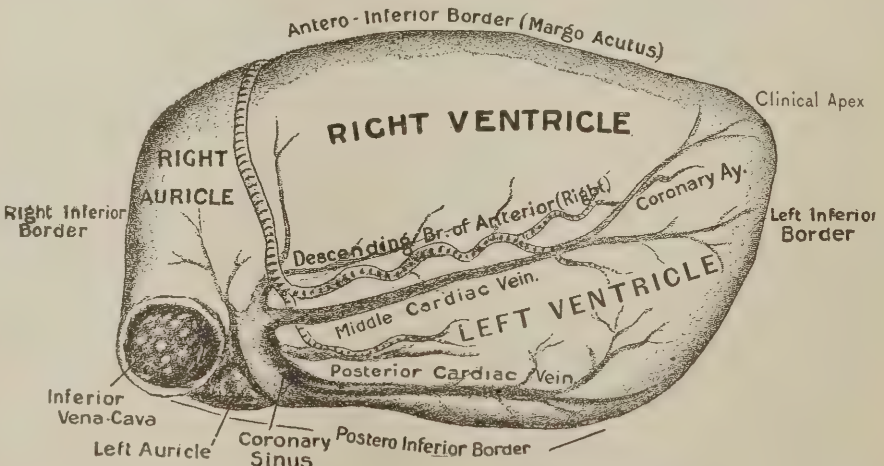

FIG. 2557.—Inferior Surface of the Heart. W. Keiller ad naturam del.

Structure of the Heart.—The heart is invested externally by a fibro-serous membrane, the *epicardium*, under which lies, especially along the interventricular and auriculo-ventricular grooves, a variable amount of fat with the main trunks of the cardiac vessels embedded therein. Its cavities are lined internally by a smooth endothelial lining, supported by a delicate fibrous membrane (the *endocardium*); the main substance of the heart is composed of muscular tissue (*myocardium*), the intricate arrangement of whose fibres will be found described under the heading *Circulation of the Blood* (Vol. III., p. 105). The valves are avascular and composed of fibrous tissue with an endocardial lining; while in the region of the ventricular orifices are fibrous rings, and between the aorta and auriculo-ventricular orifices there is a central fibro-cartilage.

Blood-Vessels of the Heart.—The *right coronary artery* (Figs. 2548, 2553, and 2557) arises from the anterior sinus of Valsalva, passes forward between the pulmonary artery and right appendix, and follows the right auriculo-ventricular groove till it reaches the inferior interventricular groove where it divides into two branches, of which the smaller *transverse* or *auriculo-ventricular* branch continues in the left auriculo-ventricular groove for some little distance, and the larger *descending* (or better, *interventricular*) branch follows the inferior interventricular groove, supplying both ventricles and the septum. This vessel in its course supplies the right auricle and ventricle, aorta and pulmonary artery. Besides the terminals it gives off two named branches, an *infundibular* branch to the front of the right conus arteriosus, and a *marginal* branch which follows the antero-inferior border to the apex. The *left coronary artery* (Figs. 2553 and 2555) arises from the left sinus of Valsalva, passes behind and then to the left of the pulmonary artery, and appears between that vessel and the left auricular appendix. Here it divides into two branches, the *anterior descending* or *interventricular* branch following the anterior interventricular groove to the apex of the heart; the *transverse* or *auriculo-ventricular* branch following the left auriculo-ventricular groove. A considerable marginal branch follows the left anterior border of the heart. It supplies the aorta, pulmonary artery, left auricle, and ventricle. The two vessels anastomose minutely with each other on the heart and with the pericardial and bronchial vessels on the walls of the aorta and pulmonary artery.

The great cardiac or coronary vein, commencing near the apex of the heart (Fig. 2553), accompanies the interventricular branch of the left coronary artery in the anterior interventricular groove; beneath the left appendix it curves backward in the auriculo-ventricular groove and joins the left end of the coronary sinus (Fig. 2556) where its opening is guarded by a valve. Three or four veins, called *posterior cardiac*, but better called left and inferior cardiac veins, course over the left and inferior surfaces of the left ventricle, joining the great coronary vein and coronary sinus. The *middle cardiac vein* (Fig. 2557), commences at the apex of the heart and follows the inferior interventricular groove with the descending (interventricular) branch of the right coronary artery. It joins the right extremity of the coronary sinus. The *small* or *right coronary vein* (Fig. 2557) runs toward the left in the right auriculo-ventricular groove to join the right end of the coronary sinus. The *coronary sinus*, about one inch in length, occupies the inferior extremity of the left auriculo-ventricular groove (Fig. 2557). It receives the veins above mentioned, all of which are guarded by valves where they join the sinus; and empties into the right auricle in front of the inferior canal opening. Its opening is guarded by the valve of Thebesius (Fig. 2550). In addition to the above a small vein, the *oblique vein* of Marshall, runs downward and over the back of the left ventricle to join the coronary sinus (Fig. 2556). This vein is interesting inasmuch as it, with the coronary sinus, represents the left superior cava of the embryo.

The *anterior cardiac veins* are two or three small veins which pass from the anterior surface of the right ventricle directly into the right auricle. They have no valves. Minute veins (the *venæ cordis minimæ*) open directly into the auricle and ventricles.

Lymphatics.—The cardiac lymphatics, found in great number beneath the lining membranes, open into both the right lymphatic and the thoracic ducts. The former are interrupted in a gland which lies between the aorta and the trachea.

The cardiac nerves are described in the article on the *Circulation of the Blood* (Vol. III., p. 113).

William Keiller.

HEART, DEVELOPMENT OF THE.—The vertebrate heart arises in two distinct ways, each of which is intimately associated with the origin of the blood-vessels in general. In the lower vertebrates its first appearance is in the form of a single tube on the ventral median line of the embryo, quite near the head. Fig. 2558 is a section of a salamander embryo in which the heart is just beginning to form. The body cavity, *lh*, is composed of two lateral halves (see *Cœlom*) separated from each other by a median septum. It is in this septum that the heart first makes its appearance. The two layers which contain this septum become separated, and the opening soon becomes lined with a layer of cells, *end*, the endocardium. The cells of the septum surrounding the opening give rise to the muscle walls of the heart.

In higher vertebrates the heart is first formed by the union of two tubes arising from what may be called the outside of the body. Fig. 2559 is a surface view of a young rabbit embryo in which the heart is beginning to form on either side of the body. The omphalomesenteric veins on either side run toward the ventral median line, and later on unite. Their appearance is such, however, that before they are united they may be spoken of as two hearts. Fig. 2560 is from a section through an embryo of the same stage as that pictured in Fig. 2559. The neural canal, *rf*, is just beginning to close, and in the splanchnopleure on either side there is a large fold, *ahh*, which already contains the endothelial tube coming from the omphalomesenteric vein. The tubes grow toward the median lines, but before they unite each has its descending aorta, as shown in Fig. 2561. The rudimentary hearts are formed between the splanchnopleure and entoderm, and as the former surrounds the heart to form its muscular layer the heart protrudes into the cœlomic cavity (Fig. 2560), much as does the single heart of lower vertebrates (Fig. 2558). Soon the two halves unite as indicated in Fig. 2561, and then we have a single heart with two veins entering from behind and two arteries, aortæ, leaving from in front. Although this primary division has nothing whatever to do with the later separation of the heart into its two halves, yet before the two primary hearts are united into a single tube the position

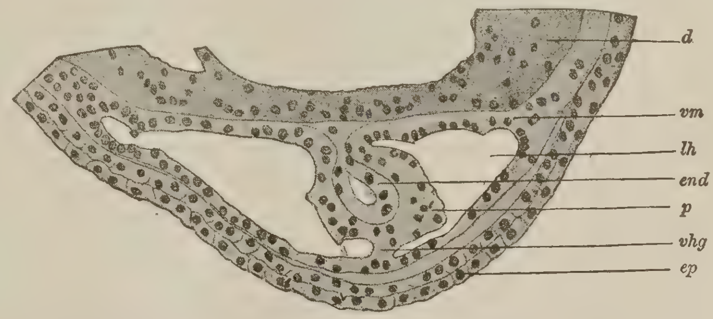

FIG. 2558.—Section through a Salamander Embryo, to Show the Origin of the Heart. (From Hertwig, after Rabl.) *d*, Yolk; *vm*, pericardium; *lh*, body cavity; *end*, endocardium; *p*, muscle layer of the heart; *ep*, epidermis.

of the ventricle is already marked (Fig. 2561, *h*). So, to sum up, in the lower vertebrates the heart appears as a single tube which in general remains such during the life of the animal, and it must be viewed as the primitive form of heart. Higher in the animal scale the heart arises before the foregut is formed, from that portion of the splanchnopleure which later on lies in the median line of the embryo. It is this part which is to give rise to the heart, and in the higher animals the heart arises before the lateral parts have reached the median line (Hertwig).

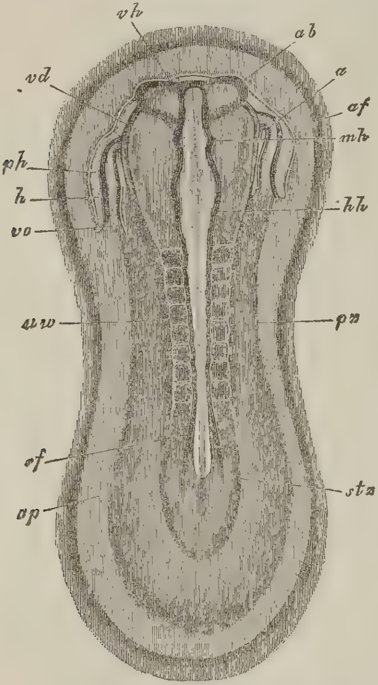

Fig. 2559.—Rabbit Embryo of the Ninth Day. (After von Kölliker.) × 10 times. *h*, Double origin of the heart; *ab*, optic vesicle; *vh*, forebrain; *mh*, midbrain; *hh*, hindbrain; *rf*, medullary groove; *uw*, myotomes; *h*, heart; *vo*, vena omphalo-mesenterica.

The two hearts then unite into a straight tube which is destined to become separated into the right and left hearts of the adult.

Fig. 2562 is a ventral view of two chicks just after the two primary tubes of the heart have united. It is seen that the veins (1) enter from behind, but the relation is soon changed by the heart becoming bent as is already indicated in Fig. 2564.

Fig. 2563 shows the general form of the heart in a very young human embryo. The front of the thorax has been cut away, the incision also extending through the transverse septum and opening the body cavities. The entrance of the veins still lies behind, and the aorta in front, but the heart has already formed one complete loop, making of it an S. Fig. 2564 is a profile of the same embryo, and the heart is indicated as a cast of its cavity. It shows the variations in calibre of the tube throughout its length. At a somewhat later stage the heart is bent upon itself more, and its walls have also become thickened. Figs. 2565 and 2566 are ventral and lateral views of a reconstruction at this stage. The profile view again gives a cast of the heart cavity, which now shows the beginning of the auricle (*V.h.*). At this time the heart is partly tilted over and the veins enter on the dorsal side. Viewed from in front, the auricles, which are just appearing, cannot be seen because they now lie on the dorsal side. A stage later (Figs. 2567 and 2568), the adult form can already be recognized. The heart has undergone a half revolution and has reached the S form. The veins enter nearer the head and the artery arises behind, or away from the head.

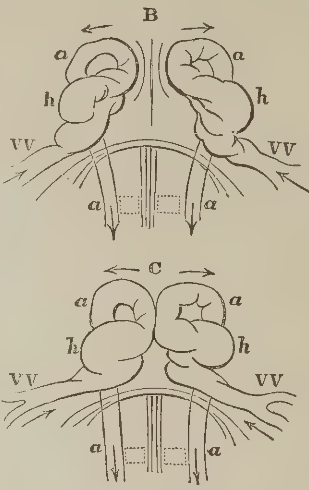

Fig. 2561.—Sketches Showing the more Advanced Condition of the Bitubular Heart of the Rabbit. × 22 times. (After Allen Thompson.) *C* is more advanced than *B*. *VV*, omphalo-mesenteric veins; *h*, heart; *a*, aorta; the arrows indicate the direction of the circulation.

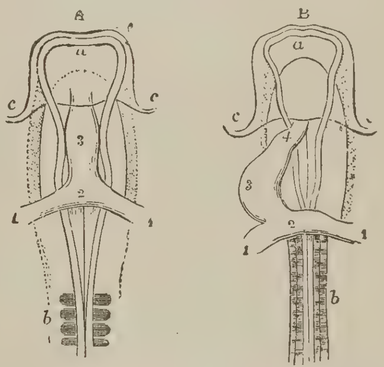

Fig. 2562.—Outlines of the Anterior Half of the Chick Viewed from the Ventral Side, Showing the Heart in its Earlier Stages of Development. × 20 times. (From Quain, after Remak.) *A*, Thirty hours; *B*, forty hours; *a*, anterior cerebral vesicle; *b*, myotomes; *c*, cephalic fold; 1, omphalo-mesenteric veins; 2, 3, 4, the heart.

The aorta lies upon the ventral side and the auricles clasp it from the dorsal. Fig. 2568 shows the great irregularity of the cavity.

A profile view of a heart of this stage is shown in Fig. 2569, which shows the relation of the heart to the surrounding organs. The auricle (*A*) is now in front and the ventricle (*V*) behind. The larger veins enter on the dorsal side by one common opening into the right side of the auricle, the future right auricle.

After the heart has once reached this stage it is only to be separated into its right and left tubes to produce the mammalian heart. In some of the lower animals this never takes place, and in others it is only partial. In cases of arrested development the human

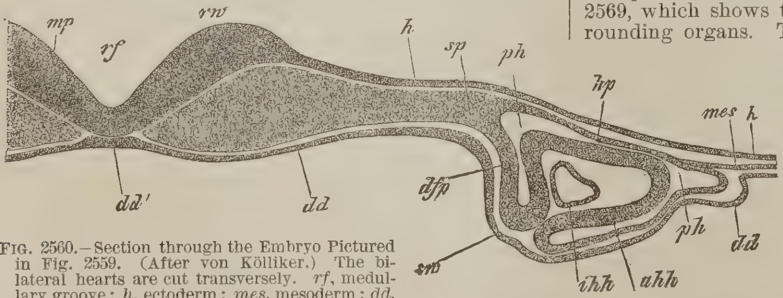

Fig. 2560.—Section through the Embryo Pictured in Fig. 2559. (After von Kölliker.) The bilateral hearts are cut transversely. *rf*, medullary groove; *h*, ectoderm; *mes*, mesoderm; *dd*, entoderm; *dd′*, chorda; *ahh*, muscle wall of the heart; *ihh*, endothelial lining of the heart.

heart in the adult may show any of its embryological forms, as, for instance, an open foramen ovale.

Figs. 2570 and 2571 show the interior of two stages of early human hearts, taken from models made by His. In Fig. 2570, the auricle is enlarged and the vein enters on the right side. The ventricle is considerably smaller and its walls are much thicker than those of the auricle. This is usually the case with the hearts of embryos, as they die with the ventricles contracted and the auricles filled with blood. Between the two there is a narrowed auriculo-ventricular canal and with a corresponding constriction on the outside of the heart. Fig. 2571 shows a more advanced stage. The general state of the heart is much as it is in the Fig. 2570, only that the auricles are "shoved" into the ventricle. This is of considerable importance, as we shall see later on. In both cases the aorta arises from the right side of the ventricle, and in its further development one-half of it must be transferred to the left side in order to produce the aorta proper, while the half which remains becomes the pulmonary artery.

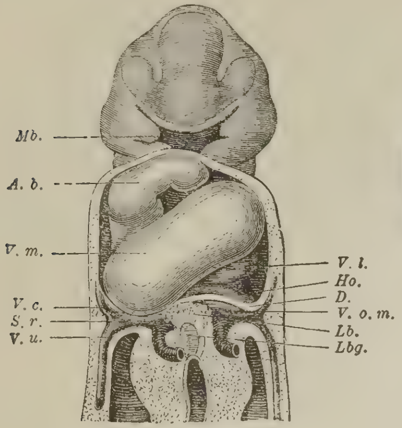

FIG. 2563.

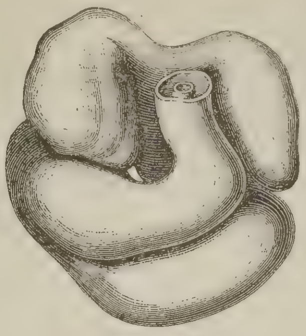

FIG. 2567.

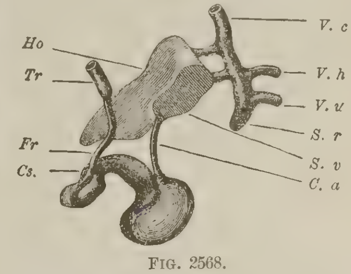

FIG. 2568.

FIGS. 2567 AND 2568.—Ventral and Profile Reconstruction of His' Embryo, Bl. × 40 times. *Ho*, Auricle; *C.a*, auriculo-ventricular canal; *Tr*, aorta.

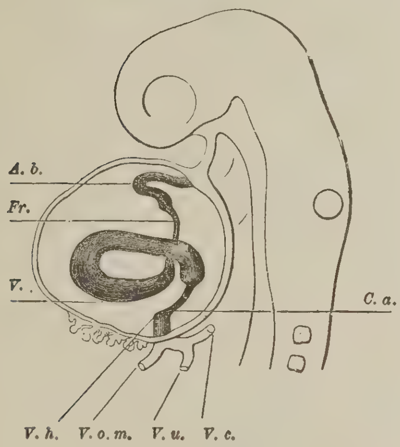

FIG. 2564.

FIGS. 2563 AND 2564.—Ventral and Profile Reconstructions of His' Human Embryo, Lg. × 40 times. (After His.) In the profile view only the outline of the cavity of the heart is shown. *V.*, Ventricle; *A. b.*, bulbus aortæ.

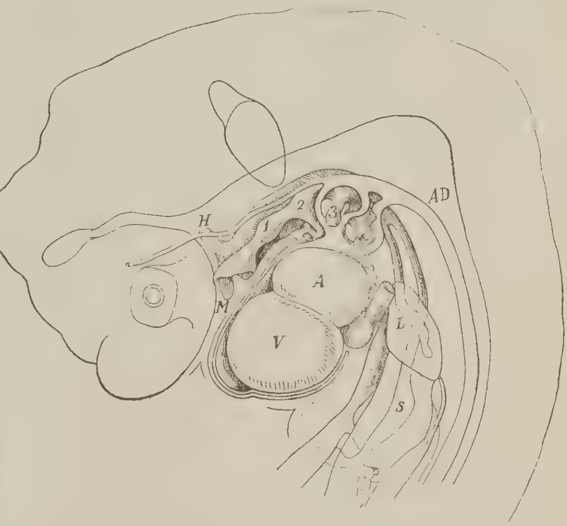

FIG. 2569.—Reconstruction of a Human Embryo enlarged sixteen times, and viewed from the left side. *H*, Hypophysis; 1, 2, 3, and 4, branchial pockets; *M*, mouth; *A*, auricle; *V*, ventricle; *AD*, descending aorta; *L*, lung; *S*, stomach; *P*, pancreas.

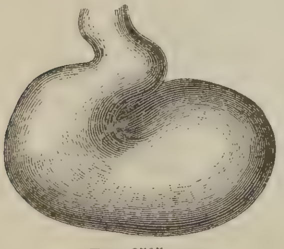

FIG. 2565.

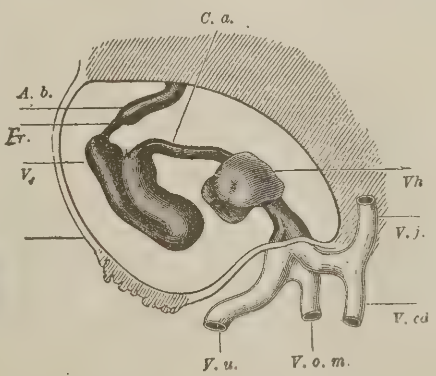

FIG. 2566.

FIGS. 2565 AND 2566.—Ventral and Profile Reconstruction of His' Embryo, Lr. × 40 times. (After His.) *V*, Ventricle; *Vh*, auricle; *A. b.*, bulbus aortæ.

The first important change in the separation of the heart into its two lobes is the formation of two septa, one arising in the auricle, *S.s.*, which grows backward, and one in the ventricle, *S.inf.*, which grows forward. At the same time that these are growing toward each other, a cushion of connective tissue, *s.i.*, is formed upon the two lips of the slit-like auriculo-ventricular opening which aids to complete the septum of the heart. This cushion, or septum intermedium, soon separates the auriculo-ventricular opening into two canals, the right and the left, to become the right and left auriculo-ventricular canals, respectively.

The septum of the auricle is com-

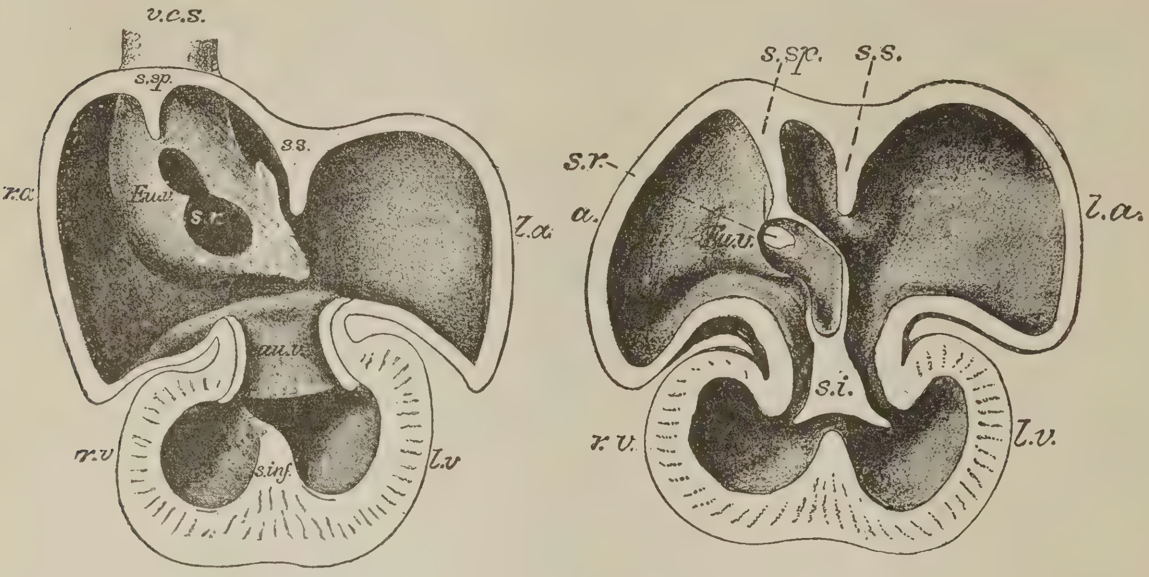

FIG. 2570.

FIG. 2571.

FIGS. 2570 AND 2571.—Two Stages in the Formation of the Septum Intermedium in the Heart of the Human Embryo. (From Quain, after His.) In Fig. 2570 the septum is represented as growing from a triangular area to the left of the sino-auricular orifice; in Fig. 2571 it has coalesced with the endocardial cushions, and lies like a stopper in the auricular canal. *r.a.* and *l.a.*, right and left auricle; *r.v.* and *l.v.*, right and left ventricle; *s.r.*, sinus reuniens; *Eu.v.*, Eustachian valve; *s.sp.* septum spurium; *s.s.*, septum superior; *s.inf.*, septum inferior; *s.i.*, septum intermedium; *v.c.s.*, vena cava superior dextra.

pleted by the septum superior growing backward to unite with the septum intermedium. Before this takes place, however, several changes take place in the septum (Figs. 2572, 2573, and 2574). These figures represent three stages of a lateral view of the two septa above named, with the opening between them. In Fig. 2572, the septum superior is forming, but the S. intermedium is not yet complete. It was at first thought that the opening between them, *O′*, produced the foramen ovale, but later observations by Born showed that there is a

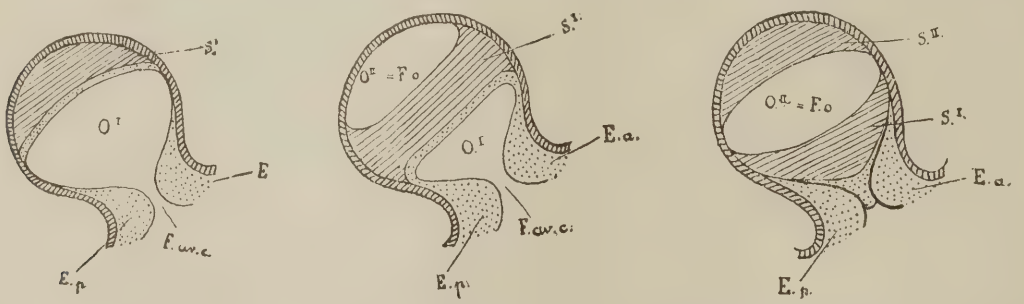

FIG. 2572.

FIG. 2573.

FIG. 2574.

FIGS. 2572, 2573, AND 2574.—Side View of Three Stages, to Show the Formation of the Foramen Ovale. (After Born.) *S′*, First portion of the superior septum: *S″*, second portion of the superior septum; *O′*, first foramen ovale; *O″*, secondary opening or true foramen ovale; *E.p.*, endothelial cushion in the auriculo-ventricular opening.

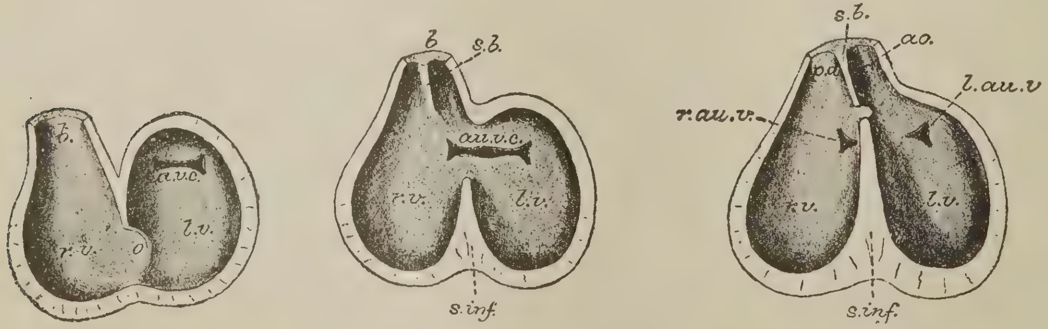

FIG. 2575.

FIG. 2576.

FIG. 2577.

FIGS. 2575, 2576, AND 2577.—Diagrams to Show the Formation of the Septum of the Ventricles and Bulb, and the Mode of Division of the Common Auriculo-ventricular Aperture. (From Quain, after Born.) *r.v.* and *l.v.*, right and left ventricles; *s.inf.*, inferior septum: *b.*, bulb of aorta; *s.b.*, septum bulbi; *au. vc.*, auriculo-ventricular canal; *ao*, aorta; *p.a.*, pulmonary artery.

secondary rupture in the septum superior which is destined to become the true foramen ovale (Fig. 2573, *O″*). The portion of the septum superior which has been cut off by the formation of the foramen ovale, unites with the septum intermedium as shown in Fig. 2573. The secondary septum, *S″*, later on forms the limbus of Vieussens, and the first, *S*, the valve of the foramen ovale.

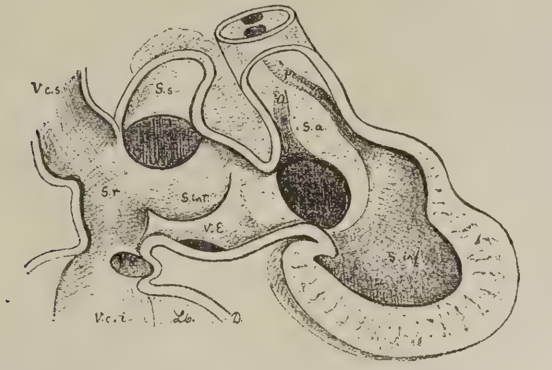

FIG. 2578.—Opened Heart of a Human Embryo Seen in Profile. × 33 times. (After His.) *p.*, Pulmonary artery; *a*, aorta; *S.a.*, septum aorticum; *S.inf.*, septum inferior; *S.s.*, septum superior; *S.int.*, septum intermedium; *v.e.*, Eustachian valve; *S.r.*, sinus reuniens; *V.c.i.*, vena cava inferior; *Lb.*, liver; *D*, diaphragm.

A partial septum of the heart is first met with in certain classes of ganoid fishes (Dipnoi), where it arises by a union of muscle columns in the auricle. This is a very incomplete septum, which is gradually increased in the amphibia. In neither of these cases has the septum reached the auriculo-ventricular opening. This gives us an auricle partly divided, both compartments communicating with each other, and through a common opening with a single ventricle, much as is shown in the heart of the human embryo pictured in Fig. 2570. In the reptiles the septum is complete, and we have two distinct auricles communicating independently with the ventricle. We can view this as the completion of the second stage, *i.e.*, a complete union of the septum superior and the septum intermedium. In birds and mammals, however, there is a secondary rupture of the septum of the auricle; in the former it is multiple, and in the latter, as a rule, single. It is therefore seen that the formation of a secondary or true foramen ovale, as described by Born, is confirmed by the comparative anatomical evidence (see Born, *Arch.*

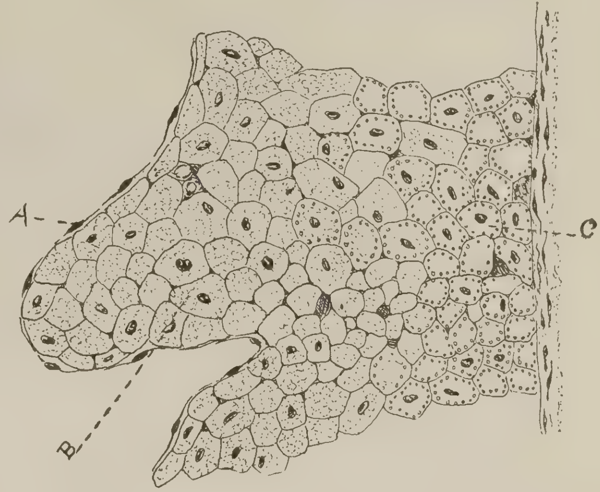

FIG. 2580.—Section of the Wall of the Heart Ventricle from an Embryo Pig 12 mm. Long. (After MacCallum.) The left side of the figure represents the inside of the heart. *A*, Endocardium covering a papillary muscle; *B*, cross section of cells containing a simple network, and therefore very young; *C*, older cells containing fibril bundles.

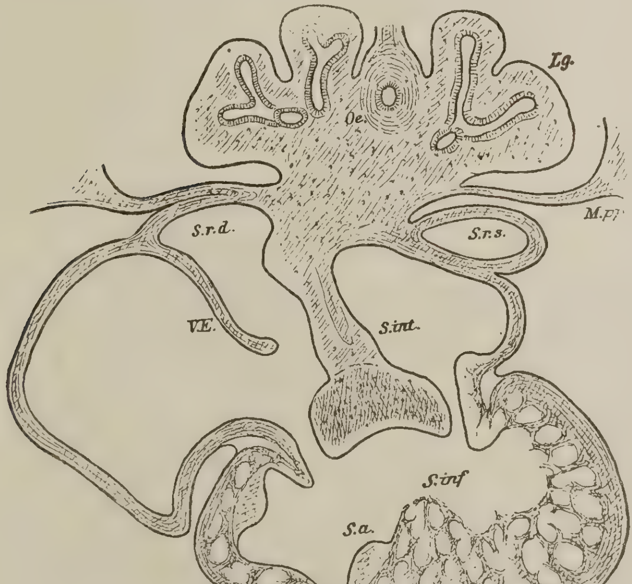

FIG. 2579.—Section through the Heart of a Human Embryo to Show the Formation of the Columnæ Carneæ. × 36 times. (After His.) *Oe.*, œsophagus; *Lg.*, lung; *M.pp.*, membrana pleuro-pericardiaca; *S.r.d.* and *S.r.s.*, right and left horns of the sinus reuniens; *V.E.*, Eustachian valve; *S.int.*, septum intermedium; *S.inf.*, septum inferior; *S.a.*, septum aorticum.

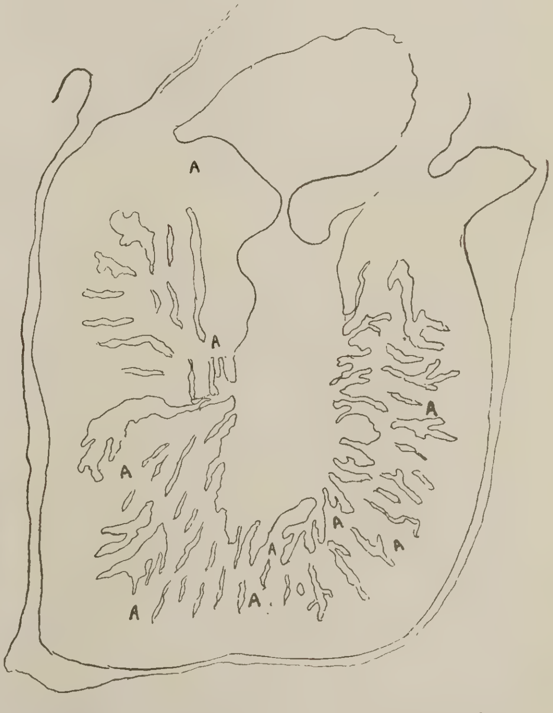

FIG. 2581.—Longitudinal Section of a Heart Ventricle from an Embryo Pig 16 mm. Long. (After MacCallum.) *A*, Position of karyokinetic figures.

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The opening of the vein is guarded by two folds of the walls of the heart, which really form a complete bicuspid valve (Fig. 2571). An additional fold extends to this from in front, the sectum spurium, *S.sp.* Later on, the orifice enlarges to incorporate a portion of the veins into the auricle, but the right lip of the opening remains permanently as the Eustachian valve. The pulmonary veins are formed later. They grow from the lungs to the left auricle.

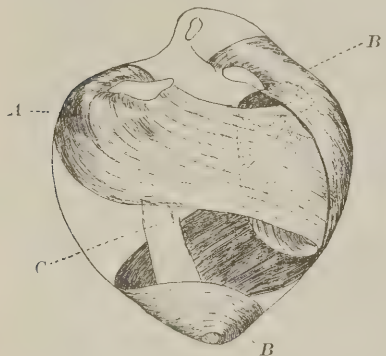

FIG. 2582.—Diagram of the Course of the Superficial Muscle Layers Originating in the Right and Left Auriculo-ventricular Rings and in the Posterior Half of the Tendon of the Conus. (After MacCallum.) *C*, Anterior papillary muscle.

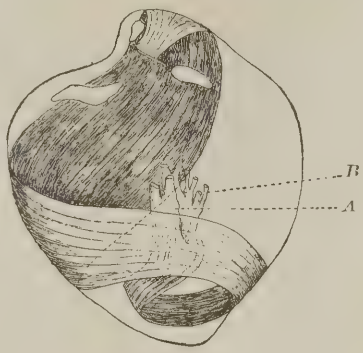

FIG. 2583.—Diagram of the Course of the Superficial Muscle Layers Originating in the Anterior Half of the Tendon of the Conus. (After MacCallum.) *A*, Posterior papillary muscle; *B*, papillary muscle of the septum.

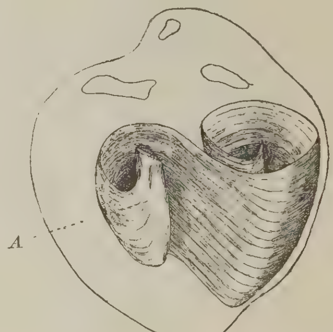

FIG. 2584.—Diagram of the Course of the Deepest Layer of Muscle of the Left Ventricle. (After MacCallum.) *A*, Posterior papillary muscle.

Returning to a stage of heart as represented in Fig. 2571, we notice that the common ventricle shows a constriction on the outside which corresponds to a septum forming on the inside. As this septum from the inside, the septum inferius, grows toward the S. intermedium, it must also grow toward the aorta to join a septum aorticum which is forming there. Figs. 2575–2577, show how this is brought about. Fig. 2575 represents a stage in which the auricles empty wholly on the left side and the aorta arises wholly on the right. As the inferior septum arises the auriculo-ventricular opening moves, as it were, toward the aorta; and when the septum inferius unites with the S. intermedium it cuts the auriculo-ventricular opening in such a manner that the blood coming from the right auricle passes to the right ventricle, and the blood from the left auricle to the left ventricle. A small opening exists for quite a while between the two ventricles, but, later on, this is closed by a membrane of connective tissue. Before the ventricles are completely separated from each other, a view of the septum appears much as is shown in Fig. 2578. The aorta is already completely separated into two vessels: the one which communicates with the right ventricle, communicating above with the fifth aortic arch, and the one from the left with the fourth. The fourth is destined to become the aorta, and the fifth the ductus arteriosus from which the pulmonary artery arises.

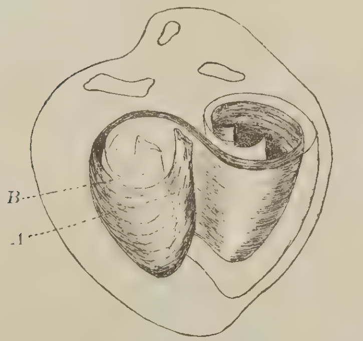

FIG. 2585.—Diagram of the Course of the Layer Superficial to that Shown in Fig. 2584. The outline of the deep layer is also shown. (After MacCallum.) *A*, Posterior papillary muscle; *B*, papillary muscle of the septum.

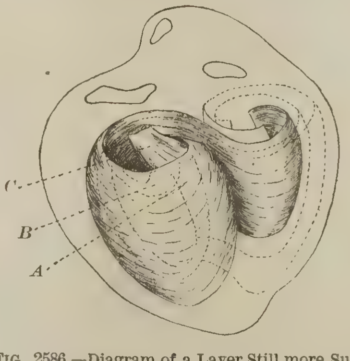

FIG. 2586.—Diagram of a Layer Still more Superficial to that Shown in Fig. 2585, and Ending in the Anterior Papillary Muscle. The other layers are represented in dotted lines. (After MacCallum.) *A*, Posterior papillary muscle; *B*, papillary muscle of septum; *C*, anterior papillary muscle.

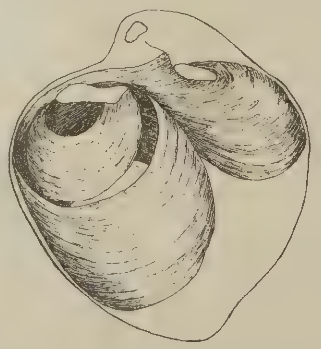

FIG. 2587.—Diagram of the Muscle Originating in the Tendon of the Conus and Upper Part of the Right Ventricle. (After MacCallum.) This layer surrounds the layers represented in the left ventricle in Figs. 2584, 2585, and 2586.

At an early stage the tissue of the ventricle walls becomes spongy on the inside. These meshes and columns play a very important part in the formation of the valves, muscle columns, and the tendons to the valves. We have seen that the septum intermedium is formed in the auriculo-ventricular canal and divides it into a right and a left half. When this is complete a section of the heart gives a picture as shown in Fig. 2579. At the same time a portion of the auricle is, as it were, pushed into the ventricle, as the figure shows. This invagination takes with it a portion of the epicardium, to be incorporated in the formation of the valve. Connective tissue is incorporated in the formation of the valve at its beginning, although the great bulk of the valve is at this time composed of muscular fibres. The burrowing of the ventricle walls includes also the valves, and in this way, as the figure indicates, the primitive chordæ tendineæ are formed. Soon, however, the bands lose their muscle fibres, in the portions which form the chordæ, and in other portions, farther away from the valve, the muscle fibres increase to form the papillary muscle. The valves have therefore a double origin: (1) Peripheral, and (2) from the septum intermedium. According to His, the tendons attached to the valves arising from the periphery, have their permanent attachment to the valve from the beginning, while a portion of those passing to the valve and arising from the septum intermedium may possibly shift their valvular attachment.

The muscle walls of the two ventricles are at first of the same thickness, but, later on, that of the left becomes heavier than that of the right. The spongy layer in the ventricle is covered with endocardium, and from this layer the columnæ carneæ arise.

Recently MacCallum has made extensive studies on the development of the heart muscle cells as well as of the arrangement of the fibre bundles in the hearts of embryos.* MacCallum has found that the heart muscle cell in its development undergoes certain changes by which younger and newly developed cells can be distinguished from fully developed cells. The difference between the older and younger cells is well shown in Fig. 2580, taken from the heart of a very young pig's embryo. It is seen that the younger cells are immediately under the endocardium and that the older cells have been pushed toward the outside and lie immediately below the pericardium. In the younger cells the nuclei multiply by indirect cell division and the distribution of such cells is shown by the letter *A* in Fig. 2581. Here again the growing point of the muscle of the heart is found to be immediately below the endocardium. It appears then that the growth of the heart after the organ is well formed is on the inside immediately below the endocardium. In some way, not yet definitely known, the heart is then gradually rolled up, becoming more and more complex in the higher animals. MacCallum has succeeded in unravelling the musculature in the embryo pig and the human fœtus before the fibres have become interlaced too much. According to him, the fibre bundles can be divided into four groups: (1) Those arising from the auriculo-ventricular ring on one side and passing to the papillary muscle of the opposite side (Figs. 2582 and 2583); (2) those bundles arising from the papillary muscles on one side and passing to the papillary muscles on the opposite side (Figs. 2584, 2585, and 2586); (3) those fibres arising from the auriculo-ventricular ring on one side and passing to the auriculo-ventricular ring of the opposite side (Fig. 2587); and (4) those fibres which simply encircle the left auriculo-ventricular ring and the aorta (Fig. 2588).

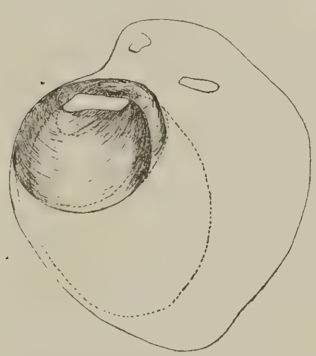

FIG. 2588.—Diagram of the Layer of Muscle Surrounding the Aorta, and Left Auriculo-ventricular Ring. (After MacCallum.) Fig. 2587 is represented in dotted lines.

According to MacCallum, the points to be emphasized in his work are as follows:

The heart consists of several layers of muscle, the course of which is shown in some detail in Figs. 2582–2588. Nearly all begin in the auriculo-ventricular ring of one ventricle and end in the papillary muscle of the other. Those fibres which begin near the outside of one ventricle end near the inside of the other ventricle.

The thin superficial muscle being removed, the left ventricle can be unrolled so that its cavity and papillary muscle are exposed. This shows it to be a flat band of muscle continuous with the muscle fibres which cross over in the septum from the right ventricle.

Grouping these layers together, it is plain that the heart in the embryo is a scroll-shaped band of muscle with tendons at each end. As it grows older the layer of muscle passing over in the septum from the right to the left ventricle remains comparatively thin, while the ventricular cells increase greatly in thickness. The place of most active cell growth is near the inside of the ventricular walls, and they are, therefore, at the two ends of the band of muscles making up the heart.

Franklin P. Mall.

HEART DISEASES: ACTINOMYCOSIS.—Actinomycosis of the heart has been observed a number of times within recent years, and it is very probable that as the reported cases of infection with actinomyces multiply this organ will be found to be not infrequently affected. Since the respiratory tract appears to be one of the most common avenues of entrance of this parasite, secondary involvement of the mediastinum is of frequent occurrence, whereby extension to the pericardium is very likely to take place. Besides infection by direct extension from the mediastinum hæmatogenous metastases in the heart wall may occur, or the heart may be primarily affected, the avenue of entrance being unknown. Paltauf found extensive actinomycosis of the wall of the right ventricle in a tuberculous subject, the condition having been diagnosed as tuberculous pericarditis. In cases observed by Israel, Ponfick, and others, metastases were found in the heart arising from primary foci in the liver, lungs, and other parts of the body (pyæmic actinomycosis). Occasionally a general infection of the body, acute or chronic, occurs, and the heart is involved in common with other organs. Actinomycosis of the heart presents no definite clinical picture. The diagnosis of the condition will rest entirely upon the demonstration of the presence of the parasite within the body. The treatment should be directed along general lines, with the internal use of potassium iodide, which in some cases has appeared to have a specific effect upon the fungus.

Aldred Scott Warthin.

HEART DISEASES: ANÆMIC INFARCTION.—The occlusion of a branch of a coronary artery, if not immediately fatal, is followed by an anæmic necrosis of the part of the heart wall supplied by the occluded vessel. The necrosed area is known as an anæmic or white infarct or as *myomalacia cordis.* The terminal branches of the coronary arteries are true end arteries, and possess but a very limited collateral anastomosis. The area of necrosis produced by the occlusion of a terminal branch corresponds to the physiological distribution of the affected vessel. Infarction occurs most frequently in the portion of the myocardium supplied by the anterior coronary artery, the most common location being in the wall of the left ventricle near the apex.

The occlusion is usually produced by thrombosis or embolism. These events are favored by sclerotic changes; under certain conditions cororonary sclerosis in itself may give rise to infarction without the occurrence of thrombosis or embolism. In such cases the nutrition of the muscle already impaired by the partial obstruction of the vessel caused by sclerosis may be so much further lowered by general circulatory disturbances that the integrity of the muscle can be no longer preserved. Thrombi are of much more frequent occurrence in the coronary vessels than emboli; their formation is directly dependent upon the occurrence of sclerotic changes in the vessel wall. The entrance of emboli into the coronary vessels is of rare occurrence. This fact is explained by the anatomical peculiarities of the coronary arteries, the location of their orifices, angle of divergence with the aorta, force of current, etc. Embolism, however, occasionally occurs; the embolus usually consists of a portion of a thrombus primary in the left heart, either parietal or formed upon the mitral or aortic valves. In other cases the embolus may consist of atheromatous material derived from the vessel wall above the point of occlusion. Septic emboli occur in cases of malignant endocarditis; they are more frequently derived from vegetations on the mitral than on the aortic valve. In whatever way produced, coronary occlusion leads immediately or very quickly to anæmic necrosis, the slight capillary anastomosis and the Thebesian vessels being inadequate to the task of supplying sufficient nutrition to the affected area.

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* MacCallum: Anat. Anz., xiii., 1897; Journ. of Experimental Medicine, iv., 1899; and Welch Festschrift, Johns Hopkins Hospital Reports, ix., 1900.

The infarct is yellowish or grayish-red in color and of a cloudy, parboiled appearance. The consistence is somewhat softer than that of the normal muscle, and the recent infarct is slightly elevated. Subsequently it becomes softer and depressed. The heart infarct is rarely wedge-shaped, as is so frequently the case in infarction of other organs; but the contour is irregular, areas of living muscle alternating with dead tissue. This irregularity of distribution is due to the peculiar overlapping of the coronary branches, as a result of which adjacent muscle bundles may receive their blood supply from terminal branches arising from different main trunks of the third or fourth degrees. This fact is of great importance in the heart economy in so far as the occurrence of infarction is concerned. Occlusion of the smaller terminals does not lead to an infarction extending entirely through the heart wall, and the chances of rupture or aneurismal dilatation are thereby much lessened. Around the periphery of the infarcted area there is almost always a narrow zone of hemorrhage and congestion outlining the yellowish dead muscle with a border of red. This is to be regarded as being of the nature of a narrow zone of hemorrhagic infarction in the limited area of collateral anastomosis between the occluded vessel and the neighboring terminal. Large hemorrhages occasionally occur about the infarct; these may extend in between the dead muscle bands of the anæmic area, giving it the appearance of a hemorrhagic infarction. Infarcts of small size do not usually involve either the peri- or the endocardium, but larger ones are accompanied by the formation of thrombi on the endocardium and localized areas of pericarditis.

On microscopical examination the muscle fibres in the central portion of the infarct show a condition of simple necrosis, their nuclei having completely disappeared, and the muscle protoplasm presenting a more or less homogeneous appearance, staining deep red with eosin. Occasionally extensive fragmentation or Zenker's necrosis may be present. Around the periphery of the completely necrosed area there is usually found a zone of diffused chromatin, the muscle nuclei at this point showing beginning or partial disintegration. Bordering upon this zone is the area of partially damaged muscle with greatly congested vessels and extensive interstitial hemorrhage. If the infarct is not of very recent occurrence extensive leucocyte infiltration may be found around the periphery, or evidences of repair in the formation of granulation tissue. In older infarcts the dead muscle is almost or wholly replaced by new connective tissue at the periphery, in which numerous hypertrophic muscle fibres may be present. Scattered throughout infarcts of large size small islands of living heart muscle are usually found corresponding to the distribution of neighboring branches. The boundary between such areas and the necrosed muscle usually shows a narrow intermediate zone of partial necrosis, diffused chromatin, and hemorrhage. In the majority of infarcts there is usually present a narrow line of living muscle just beneath the peri- and endocardium, which is to be explained by the presence of small collateral branches running beneath these surfaces.

The regeneration of heart-muscle fibres in or around healing infarcts takes place only to a very limited extent. Evidences of this are seen in greatest degree in week-old infarcts. The division figures are never very numerous, and soon disappear. It is probable that the new cells formed quickly degenerate. Hypertrophic muscle fibres are often very numerous in the immediate neighborhood of a healing infarct. This must be regarded as being of the nature of a compensatory hypertrophy. Whether an increase in the number of fibres takes place or not cannot at present be positively stated. Ultimately infarcts of small size are completely replaced by scar tissue, and the area of induration thus formed appears as a white tendinous patch or band in the heart muscle. The designation of fibroid heart or fibrous myocarditis is applied to this condition as well as to the areas of sclerosis due to obliterating endarteritis.

Septic infarction may occur in cases of pyæmia, the smaller branches of the coronary arteries may be blocked with septic emboli. Purulent inflammation of the vessel wall and the neighboring tissue results, and the area of infarction becomes converted into an abscess. Usually death results from the general condition before these develop into abscesses of large size. In the majority of cases they appear as pinhead abscesses, rarely as large as a pea. Very rarely they may reach such a size as to perforate into the heart cavity or into the pericardium, forming what has been termed acute cardiac ulcer. Embolic aneurismal dilatation of the affected coronary branch may result at the point of embolism, and rupture of this may lead to the formation of a dissecting aneurism of the heart wall.

As a result of anæmic infarction of the heart death may occur instantaneously from the disturbance of the cardiac circulation and the arrest of the fibrillary contractions. In all cases of sudden death occlusion of the coronary vessels should be carefully sought for. Particularly is this the rule in medico-legal examinations. Death may occur before recognizable changes in the structure of the muscle take place. In other cases it may not result for some time after the occlusion of the vessel. It has been shown by animal experiments that the heart muscle is capable of contraction for nearly twelve hours after ligation of the coronaries. At the present time it is impossible to say whether death occurs at the moment of occlusion of the vessel or at the moment of muscle failure. With the softening of the infarcted area either rupture or aneurismal dilatation of the cardiac wall may take place. Sudden death may be caused by the former event. After healing of an infarct the cicatricial tissue may give before the blood pressure and produce an aneurism. In many cases there is a progressive occlusion of the coronary branches with the production of multiple infarcts. A very extensive degree of fibroid heart may result from the healing of these.

The symptoms of anæmic infarction are usually those of angina pectoris. The direct relation between the anginal attack and the moment of infarction has not been sufficiently emphasized. The cases of sudden death are quite frequently preceded by an intense but brief attack of this nature. In other cases there are no definite cardiac symptoms. After healing of the infarcted areas the clinical picture is that of fibrous myocarditis. Prognosis and treatment will be considered under that head.

Aldred Scott Warthin.

HEART DISEASES: ANEURISM.—The term aneurism of the heart is applied to three very different conditions: aneurisms of the coronary vessels, pouch-like projections of the valves, and local dilatations of the heart wall. The original use of the expression cardiac aneurism was that of Avenbrugger and Corvisart, who applied it to all cardiac enlargements of the nature of hypertrophy or dilatation, distinguishing the two as *aneurysma passivum* and *aneurysma activum.* This conception continued up to the time of John Hunter and Matthew Baillie with whom the term took on its modern significance of a partial dilatation of the cardiac wall. In accordance with this idea the condition is often spoken of as partial aneurism, though in the majority of cases cardiac aneurism is taken as referring to aneurism of the wall alone, coronary and valvular aneurisms being considered under separate heads.

ANEURISM OF THE CORONARY ARTERIES.—Aneurismal dilatations of the coronary branches of the second and third degree occur as the result of sclerosis or embolism. They are usually multiple, but may be found singly. They vary in size from a mustard seed to a large cherry, and occasionally form small nodular enlargements scattered over the heart, lying just beneath the epicardium. They are found in greatest numbers and of largest size when due to septic emboli. The symptoms are those of myocarditis. They may rupture either into the pericardial cavity or into the heart wall, in the latter case forming dissecting aneurisms which may be mistaken for true aneurisms of the cardiac wall.

Aneurism of the Valves.—(See article next beyond this.)

Aneurism of the Heart Walls.—Localized dilatation of the heart wall may be congenital or acquired. In the latter case it is due either to trauma or to some pathological condition diminishing the resistance of the heart muscle in localized areas.

Congenital Form.—In defective development of the heart muscle aneurismal or hernial projections of the endocardium may occur between the muscle bundles. As a result of congenital abnormal thinness of the cardiac wall aneurismal dilatations may occur in any part of the heart, most frequently in the membranous portion of the ventricular septum. The occurrence of congenital aneurisms in individuals reaching maturity is, however, very rare, the majority of the cases being found in infants or young children.

Acquired Form.—In the majority of cases this is due to fibroid changes in the heart muscle following coronary obstruction or syphilitic infiltration, less frequently to anæmic infarction, fatty degeneration, mural endocarditis and wounds of the heart. It is not of common occurrence, though cases have been reported with increasing frequency in late years. In 1867 Pelvet collected the cases published up to his time, and in 1883 a similar collection was made by Legg, who found in the literature the reports of 90 cases. Since his article new observations have been constantly made, and the number of recorded cases is now in the neighborhood of 300. According to Willigk, 170 cases of cardiac aneurism were found in 34,000 autopsies. The acquired dilatation may be acute or chronic; according to its manner of formation it may be a pouch-like dilatation communicating with the heart cavity through a large opening, or it may be saccular with a very small opening, or the aneurism may be of the dissecting variety. Rarely it may be multilocular, consisting of a number of intercommunicating sacs.

The majority of cases occur in males of advanced age, but a number of cases in young men have been reported, and one in a young girl of twelve years. In the younger cases the condition is almost always the result of syphilitic weakening of the wall. The usual seat of the aneurism is in the anterior wall of the left ventricle near the apex, occurring in this location in 59 of the 90 cases reviewed by Legg. The septum is involved next in point of frequency, while the auricles and right ventricle are only very rarely affected. Usually the aneurism is single, but very rarely localized dilatations have been found in all four of the heart cavities. In the auricles the whole wall may be involved in the dilatation. Occasionally a number of dilatations, in one of the reported cases four, have been found side by side, their walls in apposition. The aneurismal dilatation of the septum usually protrudes into the right ventricle, but one case having been recorded of its projecting into the left.

The size of the aneurism may vary greatly, from the size of a fist to a man's head. The larger the sac, the thinner the wall. In very large sacs it may be as thin as paper without any traces of heart muscle remaining. The sac may be filled with a soft or firm thrombus. This may become calcified and the sac thus obliterated. Induration and calcification of the sac wall may also occur. Usually the pericardium becomes adherent to the epicardium over the sac, so that eventually the wall of the sac may consist of the endocardium and both the visceral and the parietal portions of the pericardium.

The acute dilatation of the heart wall is usually due to anæmic infarction or septic myocarditis, rarely to direct trauma of the heart, as in the case of stab wounds. In some cases localized degeneration or necrosis of the endocardium may make the latter the place of least resistance. The softened membrane yields to the blood pressure, is torn, blood passes through the rent and gradually undermines the heart muscle. When the area of softening is primary in the muscle the endocardium overlying the weakened spot is stretched or torn, forming a cavity into which the blood forces its way. In this manner the weakened area gradually bulges out more and more until there is a definite pouch formed. Acute aneurisms usually increase very rapidly in size, in some cases becoming as large as the heart, so that the condition has been regarded as one of double heart. Though the sac may become filled with blood clot, the wall never acquires a sufficient power of resistance, and the dilatation usually proceeds until rupture occurs.

Chronic aneurism in the great majority of cases is the result of fibrous changes in the heart muscle. The connective tissue lacking the power of contraction against the blood pressure during systole gradually becomes stretched outward or a cavity may be formed in the wall connected with the ventricle by a narrow opening. By many writers syphilitic myocarditis is regarded as the most common cause of cardiac aneurism of the slowly progressive type. That the fibrous changes are directly the result of syphilis cannot be proved in the majority of cases; much rather is the process to be looked upon as being of the nature of a chronic anæmic infarction due to the progressive narrowing of the coronary arteries through sclerotic changes, which may be due to syphilis or to other causes. In a number of cases, however, the dilatation has been found to be the direct result of gummatous changes in the cardiac wall. Further, the occurrence of coronary sclerosis and fibrous changes in the heart muscle in young individuals may be quite safely regarded as being due to syphilis. Anæmic infarction plays a much greater part in the causation of chronic aneurism than is accorded to it by the majority of writers. Small infarcts are replaced by connective tissue, and up to certain limits the tone of the wall may be preserved, but if the general tone be diminished by fatty degeneration, atrophy, etc., the area of connective tissue offering the least resistance gives way and dilatation occurs at this point. Localized areas of fatty degeneration, atrophy, etc., may of themselves be the primary factor in the production of aneurism.

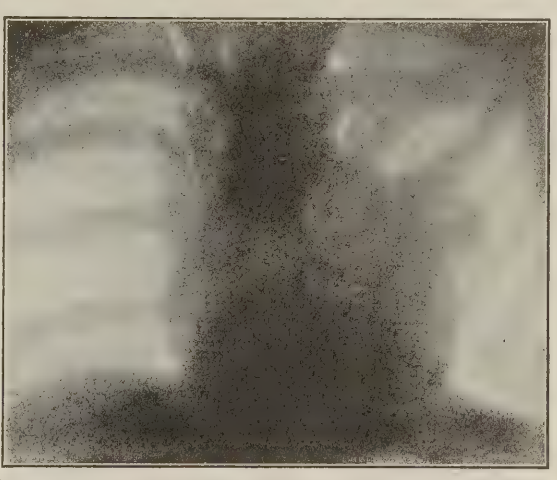

Fig. 2589.—Skiagram of a Case of Cardiac Aneurism. (After Walsham: *Edinb. Med. Journal*, April, 1901.)

Dissecting Aneurism.—The dissecting variety of cardiac aneurism deserves especial mention. Vestberg has made the most complete study of this condition. He defines it as a pathological cavity communicating with the heart or beginning of the aorta, caused by a separation of the layers of the cardiac wall by the blood. Four varieties are distinguished: parietal, septal, valvular, and interparietal. To these might be added a fifth variety when the cavity is formed between the layers of pericardial adhesions. According to Vestberg, the total number of dissecting aneurisms is 60. Of these 47 were interparietal or septal. In 30 cases the left ventricle was the site of the aneurism. The interparietal form occurs in the peri-aortic space of Vestberg, from which the blood may dissect into the auricular or ventricular septum. In 16 cases the point of origin was in the sinus of Valsalva. Acute ulcerative endocarditis is the cause in the majority of cases; in other cases abscess, atheroma, and trauma were the causal factors. Dissecting aneurisms of the aorta may extend into the walls of the heart and through secondary rupture become converted into dissecting cardiac aneurisms.

Diagnosis.—The diagnosis of cardiac aneurism is in the majority of cases impossible; it is usually made at the autopsy table. In the case of acute aneurism the symptoms are those of acute myocarditis; in the chronic form they cannot, as a rule, be separated from those of chronic myocarditis. The aneurism is usually so small as to present no characteristic physical signs. In rare cases the sac has caused erosion of the thoracic wall, forming a visible tumor. The results of percussion and auscultation are very uncertain guides, and though in individual cases unusual murmurs may be produced, they are not constant or characteristic enough to be of diagnostic significance. The Roentgen ray has recently been applied to the differential diagnosis of this condition, and the location, size, and form of the aneurismal dilatation have been shown by this means.

Prognosis.—The prognosis in the majority of cases is not favorable. In early and undoubted syphilitic cases it is relatively better. The terminations are very variable. After reaching a certain degree of dilatation the process may remain stationary. The sac may be obliterated by thrombosis; calcification of the thrombus may occur. Death usually results from cardiac insufficiency to which other factors than the aneurism may contribute. In other cases gradual increase of size with resulting rupture takes place.

Treatment.—The treatment in suspected cases is along the general lines indicated in myocardial and valvular diseases. The possibility of syphilis should always be considered. *Aldred Scott Warthin.*

HEART DISEASES: ANEURISM OF VALVES.

—A valvular aneurism is a cavity in the substance of the valve itself, containing pus and other inflammatory products, or blood clots and débris. The origin seems to be always in endocarditis of a more or less acute form, of which this is really only one of the possible results. If the process starts on the surface of the valve, ulceration may perforate one layer, after which the blood pressure dissects away the other, and so dilates the cavity that it may be as large as a pigeon's egg. On the other hand, the process may begin in the tissue of the valve and result in perforation of one of the layers from within, after which the blood pressure acts precisely as in the former case. These aneurisms are generally single, but may be multiple, and seem to be confined to the left heart. Though many authorities state that aneurisms are most commonly found in the aortic valves, the review of the literature made by Drasche shows that they are more frequently located in the mitral valve and that the anterior leaflet is more often affected than the posterior. Of the 23 cases collected by Pelvet, in 16 the aneurism was on the mitral, in 7 on the aortic valve. The perforation is almost always found on the side of the valve which is exposed to the highest pressure—the ventricular surface of the mitral, the distal surface of the aortic. The cavity may be lined by a laminated clot. The layer of the valve opposite to that containing the perforation may rupture, and the valve then suddenly become insufficient. The symptoms in such a case might be precisely similar to those of valvular rupture from any other cause.

Aneurisms have also been found, though rarely, in the valves of the right heart. As may be readily understood, valvular aneurism is of pathological rather than clinical interest, inasmuch as it betrays its presence by no distinctive diagnostic mark. Acute endocarditis can usually be detected, and so also valvular incompetence, but the precise steps which have led from one to the other in any given case must remain highly uncertain. This being the case there is, of course, no special treatment to be recommended other than that suitable to acute endocarditis. It would seem that the affection occasionally becomes chronic when seated in the mitral curtains, and is, therefore, somewhat less serious than in the semilunar cusps.

There is one other and more chronic condition which is sometimes classed as valvular aneurism. A portion of, or the whole valve, namely, may become so modified by inflammatory changes that its tissue generally yields and becomes stretched by the force of the blood pressure—both layers of the valve remaining in apposition, but being bellied out with the convexity toward the left auricle or ventricle respectively, according as the changes are seated in the mitral or in the aortic valve.

Frederick C. Shattuck.

HEART DISEASES: ANIMAL PARASITES.

—Animal parasites are but rarely found in the human heart. The echinococcus is the most frequent and the only one likely to give rise to serious symptoms. The heart is involved in about one per cent. of all cases of echinococcus infection. In a large per cent. of cases the heart alone was involved. The cysts are found much more frequently in the right side of the heart. They may vary in size from a pinhead to an orange or even larger. In one case in which the hydatid was situated in the left ventricle the enlargement of the heart was so great as to displace and compress both lungs. The cysts may be single or multiple; in one case eighty were found forming a grape-like cluster extending from the right auricle into the ventricle through the tricuspid orifice. As a rule the hydatid develops within the wall, but it may occasionally project as a pedunculated cyst into the heart cavity or into the pericardial sac. In both cases the origin of the cyst is in the myocardium, but as the hydatid increases in size the muscle is either pushed aside or becomes atrophic, and may finally disappear, the cyst then coming to project either upon the pericardial or upon the endocardial surface. The pedicle consists of a portion of the overlying pericardium or endocardium. In rare cases the cyst may extend entirely through the wall, forming a fluctuating tumor covered on one side by pericardium and on the other by endocardium. The large hydatids may contain numerous daughter cysts, varying in size from a pea to a pigeon's egg. The heart muscle in the immediate neighborhood of the cyst may show no changes or the muscle fibres may be atrophic. The thickness of the cyst wall varies from 1 to 5 mm., but this may be much increased by fibroid changes in the overlying peri- or endocardium.

Small hydatids of the myocardium not projecting into the pericardial sac or heart cavity produce no symptoms and are usually discovered only at autopsy. When the cyst projects into the cavity of the pericardium, pericarditis may be produced, and this may in turn give rise to a pleuritis by direct extension. Subpericardial hydatids, however, do not always excite pericarditis. In neither case are the symptoms characteristic. Hydatids projecting into the heart cavity are very likely to rupture. In this event sudden death may result from the embolism of the daughter cysts. In the great majority of cases the perforation is into the right heart, the cysts blocking either the tricuspid orifice or the pulmonary artery. Smaller cysts may pass through the main pulmonary branches and lead to embolism of the smaller arteries and the formation of multiple hydatids throughout the lung. Death may result in such cases from pneumonia, slowly developing pleuritis, general cachexia, etc. Partial obstruction of the pulmonary orifices may give rise to symptoms of pulmonary stenosis and insufficiency. Rupture of an echinococcus cyst into the left heart may lead to blocking of the aortic orifice with resulting stenosis and insufficiency, or smaller cysts may cause occlusion of peripheral arteries, leading to local gangrenous conditions. In one case rupture occurred into both the right and the left heart. Embolism of echinococcus cysts in the right heart or pulmonary vessels may also occur as the result of the rupture of primary hydatids into the large veins. This occurs most frequently in the case of liver hydatids.

The differential diagnosis of heart hydatids is in the majority of cases impossible. The condition may be suspected when hydatids are present in other parts of the body, or from the nature of the emboli when embolism occurs. In one of the reported cases, in which there were numerous metastases throughout the lung, small cysts were found in the sputum. Aspiration of the pericardial sac and microscopical examination of the fluid thus obtained may lead to the recognition of the condition. In those cases in which the cysts do not rupture or project into the pericardial sac the symptoms are of a very indefinite nature and may suggest either myocarditis or valvular lesions. The treatment is entirely symptomatic. In certain cases surgical interference may be of avail. Goodhart claimed to have cured a case of hydatid cyst of the cardiac wall.

The cysticercus cellulosæ is of rare occurrence in the heart, only about thirty cases having been reported. The left ventricle appears to be most frequently affected. The cysts are usually few in number, the size varying from a bean to a hazelnut, rarely larger. They may be found in the muscle or just beneath the endo- or pericardium. As in the case of the echinococcus hydatids they may project from the endocardial surface into the blood stream, being attached to the wall by a slender pedicle formed by the endocardium. The layer of endocardium over the cyst may become very much thickened. The condition cannot be diagnosed during life, the symptoms being of a very indefinite character or entirely wanting.

Trichina spiralis is stated by many writers never to occur in heart muscle, but cases of such occurrence have been observed by Leuckart, von Zenker, and Fiedler. Pentastoma denticulatum has also been found in the heart wall. In the case of both of these parasites the affection of the heart is of pathological interest only.

Aldred Scott Warthin.

HEART DISEASES: DISPLACEMENTS.—DEFINITIONS AND VARIETIES.—The heart, in a state of health, is subject to certain changes of position, caused, first, by the respiratory movements, and, second, by alterations in the bodily posture. Abnormal displacements of the organ may be either congenital or acquired. The latter only—or those that occur as the result of disease—will be considered.

In studying the displacements of the heart it is important to remember that the organ is held *in situ* directly by the great vessels, and only indirectly, through the pericardium, by the diaphragm. The attachments, fixing only the base of the heart, permit free play to the body of the organ, which hangs loosely in the pericardial sac, and very easily undergoes displacement laterally or vertically, while its dislocation either forward or backward is exceedingly rare. This statement, however, points only to a broad general classification of the disorders in question, since the heart is very seldom displaced in an absolutely horizontal, or in an absolutely vertical, plane.

MORBID ANATOMY.—It is noteworthy that the amount of dislocation actually found after death is usually less than the physical signs during life have led one to expect. The most obvious, though less important, change which the heart undergoes is a disturbance of its normal relations to adjacent structures. Compression of the cardiac walls, which may occur to a greater or less degree in the pressure class of cases, may be the more important condition. The pericardium is sometimes displaced with the heart, or greatly stretched, and the great vessels at the base of the heart and at the root of the neck may be stretched and twisted, their change in position varying with the direction and extent of cardiac displacement. In some instances the circulation in the vessels is seriously impeded. Occasionally the pericardium and heart become adherent, and adhesions between the pericardium and pleura fix the heart in its abnormal position.

The functional disturbances resulting from these alterations vary with the cause of the displacement. In those which are due to pressure, the heart, if healthy, suffers little or no real compression, even when the dislocation is effected rapidly; and if it is displaced in front of, and in contact with, a solid tumor, such as an aneurism, a solidified lung, or the spinal column, its impulses may be so vigorous and diffused as to be mistaken for cardiac hypertrophy. But if the heart is diseased, and especially if its walls are degenerated, or its cavities much dilated, sudden compression, although moderate, may cause embarrassment of the cardiac action, and even induce a fatal syncope. In those displacements which are due to retraction of either lung, the heart is displaced toward the retracted side, partly by traction, and partly by extra-distention of the opposite lung, and the effects upon the functional activity of the heart are comparatively slight. In very rare cases the heart, when displaced, becomes involved in the inflammatory process of the lung or pleura, which leads to the displacement, and fibroid changes in its walls, occurring secondary to adhesions, ultimately interfere greatly with the heart power.

ETIOLOGY.—The causes of acquired displacement of the heart are most conveniently arranged in two classes: first, conditions that exert pressure, and second, conditions that exert traction upon the heart. On the same principle all cardiac displacements have been placed under the two heads of "excentric" and "concentric." In the former of the above classes, the heart may be pressed or pushed out of position by fluid effusions into either pleural cavity. This is by far the most frequent cause of lateral displacement. Pneumothorax will also push the heart to one side, and when accompanied by perforation and inflammatory effusion, will carry the displacement to its utmost possible limit. Hydrothorax being usually double, and, therefore, pressing equally on both sides of the heart, does not displace the organ laterally, but downward. Intrathoracic tumors, aneurisms, and abscesses sometimes press the heart to the right or the left. Hypertrophy and emphysema, or other causes of enlargement of the lungs, occasionally operate in the same way, as also does extensive peumonic consolidation. Pericardial effusion, when considerable, but not extensive, may push the apex into a position corresponding to the left nipple, or even above it. Cardiac displacement may also depend upon various abdominal conditions, as gaseous distention of the stomach and intestines, enlargement of the liver or spleen, the pregnant uterus, abdominal tumors or ascites. Diaphragmatic hernia or abscesses in extremely rare cases cause displacement of the heart upward.

In the second class of cases the displacement is concentric, that is, toward the origin of the displacing force. This movement takes place during absorption of pleuritic effusions, with imperfect expansion of the lung; and in consequence of a fibroid phthisical process or cirrhosis of the lung causing a gradual decrease in its volume. The heart also suffers traction in some forms of deformity of the chest dependent upon curvature of the spine. It must be observed, however, that in all these instances the displacing force is in reality one of pressure, resulting in displacement from removal of the normal counter-pressure. In certain cases, however, actual traction undoubtedly occurs, as when the pericardium becomes involved in a cirrhotic process in the lungs, or in an adhesive pleurisy, and it and the heart are displaced by the subsequent retraction.

Since displacement of the heart is a purely mechanical process, its motion will be subject to the universal law of moving bodies; that is, it will take the direction of least resistance, or of the resultant of all the acting forces. The more common elements of this resultant are:

1. The restraining force of the cardiac attachments, particularly at its base.

2. The density and resistance of the surrounding tissues. This latter may be positive, as in case of a solid tumor, or negative, as in pneumothorax.

3. The weight of the heart is, as a rule, of slight importance. In cardiac hypertrophy, however, it may be sufficient to produce temporarily, during decubitus on the left side, a decided displacement.

4. The direct exciting cause either of pressure or of traction.

These elements may produce one or both of two forms of motion—either distinct displacement or rotation of the heart about one of its axes. Rotation, owing to the peculiar attachments of the heart, is almost invariably about the long axis, or a fixed point at the base.

Passing now to a special consideration of the causes operative in the several varieties of displacement, we find that displacement toward the left, which is most common, is brought about by contraction of the left lung by accumulation of fluid or air in the right pleural cavity, or by solid enlargements of the right lung or right lobe of the liver. Displacement toward the right is most frequently due to the presence of fluid or air in the left pleural sac, but may also result from contraction of the right lung consequent upon chronic pleurisy or fibroid phthisis; and from the development of tumors in the left side of the chest or mediastinum. Displacement downward may be caused by aneurisms or solid tumors, emphysema of the lungs, etc., in the thorax, or by collapse of the stomach or intestines. Displacement upward may be due to solid, liquid, or gaseous accumulations in the abdominal cavity, ovarian tumors, enlargement of the liver, fibroid tumors of the uterus, etc. Enlargement of the left lobe of the liver usually displaces the heart upward and to the left, while great enlargement of the spleen may push it upward and to the right. Enlargement of the liver from abscesses will also raise the organ somewhat, a fact which may become very valuable as a means of distinguishing between hepatic abscess and abscess in the abdominal wall over the liver. Another cause of this displacement is contraction of the upper part of either lung, the most common pathological condition being phthisis. Forward displacements are usually caused by an aneurism, or a solid tumor in the posterior mediastinum. Backward displacement may be produced by tumors in the anterior mediastinum, collections of air, pus, or blood in the same situations, or a posterior exostosis of the sternum.

Symptoms and Physical Signs.—Simple displacement of the heart, unattended by compression of its walls or torsion of the great vessels, causes no distinctive subjective symptoms. This is especially true when the displacement has been gradual. When it has been rapid, however, or is due to pressure, symptoms of embarrassed cardiac action may be developed suddenly. They commonly consist of præcordial oppression, more or less severe pain, amounting even to true angina; palpitation with its accompanying peculiar sense of lack of breath, which may increase until it becomes absolute dyspnœa; a weak, irregular pulse, and a pale or cyanotic countenance. Such sudden compression results most frequently from a rapidly developed gaseous distention of the stomach or intestines, and may quickly become dangerous, and, if not relieved, produce collapse and death.

Lateral displacements are usually more readily detected when occurring toward the right than toward the left side. In the former case the apex beat not infrequently corresponds to the right nipple, between the fifth and seventh ribs, the apex itself being usually raised by the width of an intercostal space above the normal level. In displacement toward the left the apex beat may be observed in the axillary region, with little or no perceptible movement at the normal situation of the apex.

Dr. Douglas Powell has shown that in right lateral displacement the apex of the heart is depressed, but never so as to occupy a position external to the base; whereas in displacements to the left the apex is relatively elevated, and the long axis of the heart is nearly or quite horizontal. According to Hayden, the distinctive features of lateral displacement from liquid effusion into the opposite pleura are the slow and mensurable mode of its occurrence; percussion dulness on the side whence the heart has been displaced, and clearness on the opposite side, beyond the limit of cardiac dulness; and, in the event of the removal of the displacing medium, return of the heart to its natural situation, or beyond it when the lung previously compressed has become incapable of expansion. Since the apex of the heart is so much more movable than its base, it is evident that, in cases of displacement, the maximum points of its sounds will not be equally removed from their normal situation. Thus, in left pleuritic effusion, when the maximum point of the first sound is carried out of place to the extent of seven or eight inches, the maximum point of the second sound is scarcely ever changed more than an inch and a half. In displacement to the right a systolic murmur has been noticed, which is ascribed to a twisting of the great vessels. When displacement of the heart is caused by cancer of the lung or pleura—with or without effusion of serum—two diagnostic symptoms of great value are especially to be noted, viz., enlargement of the subcutaneous veins of the affected side of the chest, and distinct transmission, on the same side, of the sounds of the heart. These signs, when accompanied by dulness on percussion, absence of respiratory sounds, and vocal fremitus, except at the root of the lung, and by excentric displacement of the heart, become pathognomonic of cancer of the lung or pleura.

In downward displacement the heart not only lies lower than usual, but it generally sways a little to the right. Displacement in this direction is limited by the diaphragm, and by the attachments at the base of the heart. It is most frequently caused by emphysema of the lungs, which constitutes, in fact, one of the most valuable signs in this form of displacement. If the apex beat is perceptible at all, it is situated below and to the left of its normal position. There is pulmonary resonance instead of dulness in the præcordial area, and the cardiac sounds are transferred to the epigastric triangle and the lower left cartilages.

Upward displacement appears to reach its maximum when resulting from ovarian dropsy. In some of these cases distinct impulse is not to be felt below the second interspace. The sounds of the heart are carried upward and weakened. In pericardial effusion the cardiac impulse may correspond in position to the left nipple, or even be shifted farther in that direction. When the effusion is very copious the apex beat may be completely obscured.

Backward displacement occurs most frequently in connection with other forms of dislocation. It is unaccompanied by any physical signs due directly to the condition itself.

Forward displacement is ascertained with difficulty. The physical signs are: Increase of the area and strength of pulsation and of præcordial dulness; bulging of the same sometimes is noticed in young subjects. The cardiac sounds are intensified.

Diagnosis.—The diagnosis of acquired displacements of the heart is to be made by the position of the apex beat, and of the impulse of the organ generally, by the altered locality of cardiac percussion dulness, and by the comparative intensity of the heart's sounds, more especially of the first, at different parts of the chest. The chief conditions which simulate cardiac dislocation are the following: Physiological displacements, to which reference was made at the outset; præcordial bulging in cardiac hypertrophy; intrathoracic tumors and aneurisms lying behind the heart and pushing it forward—thus producing the closest possible resemblance to cardiac hypertrophy; adhesions of the pericardium; atrophy of the lungs.

Prognosis.—Displacements of the heart being, in most instances, attended by only a slight amount of functional disturbance, and oftentimes by none at all, their prognosis is determined by the disease in which they originate. As already mentioned, when they are accompanied by sudden and violent compression of the heart, these symptoms, if not relieved in time, may result fatally. Usually, however, the direct consequences of these displacements are annoying rather than serious.

Treatment.—There is no direct treatment of cardiac displacements, they are to be remedied only by the removal of their cause; but this, in the traction class of cases, is very rarely possible. In those, however, which result from pressure, treatment is often both urgently indicated and highly successful. The troublesome pulsation which is sometimes experienced may frequently be relieved by the simple application of a belladonna plaster, with assurances as to the unimportance of the symptom. *Alfred L. Loomis.*

HEART DISEASES: ENDOCARDITIS.

HEART DISEASES: ENDOCARDITIS.—Endocarditis is an inflammation of the endocardium, *i.e.*, of the membrane lining the cavities and valves of the heart. In the great majority of cases the valvular endocardium is alone involved.

Classification.—Endocarditis is divided into two large classes, acute and chronic. We shall confine ourselves chiefly to a description of the acute form. Chronic endocarditis is practically synonymous with chronic valvular disease of the heart.

Acute endocarditis is divided into benign and malignant. These are differentiated both clinically and pathologically. The synonyms of benign are simple, rheumatic, verrucose and papillary; those of malignant are ulcerative and infective. It must be remembered that the distinction between benign and malignant is one not of kind, but of degree, as all stages between the two are found, and the same bacteria may be present in both.

History.—Bouillaud first recognized endocarditis as a distinct disease, publishing an account of it in his work on the heart and vessels in 1824. The discovery of the stethoscope by Laënnec made it possible to recognize endocarditis during life. Previous to this time it was impossible to diagnose this disease with any degree of certainty on account of its indefinite and unreliable symptomatology. In 1814 Kreysig of Dresden devoted special attention to inflammation of the lining membrane of the heart. Bouillaud by means of the signs furnished by Laënnec was able accurately to localize the endocarditis on certain valves. He declared there was a close relationship existing between rheumatism and endocarditis. He also called attention to the fact that other diseases than rheumatism, for instance, pneumonia, might produce endocarditis. He recognized likewise the fact that the acute form might be attended by symptoms of pyæmia. Virchow described the process of embolism, thus explaining the obscure complications on the part of the brain and kidneys, so intimately associated with endocarditis. Following this the important additions to our knowledge of the disease have been made by bacteriologists. Klebs in 1878 was the pioneer and insisted upon it that the various bacteria of any one of the infectious diseases might colonize on the endocardium and produce endocarditis. He showed that both the benign and the malignant forms were caused by bacteria. Litten found the same micro-organism in both forms and showed that there was no abrupt, but only a gradual difference between the two. Since this time multitudinous investigations have been made by bacteriologists all over the world, largely increasing our knowledge of the etiology of the disease.

Bacteriology.—The following bacteria have been found in the vegetations of endocarditis: Streptococci, staphylococci, pneumococci, and gonococci most frequently; less often the bacteria of typhoid fever, anthrax, diphtheria, tuberculosis, influenza, and the Bacterium coli communis.

Etiology.—Acute endocarditis is in most cases a product of bacterial activity. It is usually secondary to the various infectious diseases. When, as rarely happens, a causative factor cannot be found, it is termed cryptogenetic. Bacteria cannot always be demonstrated, but this may be due to the fact that they are likely to disappear as the vegetation becomes old. Sometimes it is possible to demonstrate them only by culture methods.

Since the time of Bouillaud acute articular rheumatism has been recognized as the most important associate of endocarditis. It is incorrect to speak of it as a cause, since it, like endocarditis, is the result of bacterial activity, with different localizations. When the germ or its toxin attacks the joint it is rheumatism; when the endocardium, endocarditis. In a certain percentage of cases, the pericardium is attacked either alone or together with the endocardium.

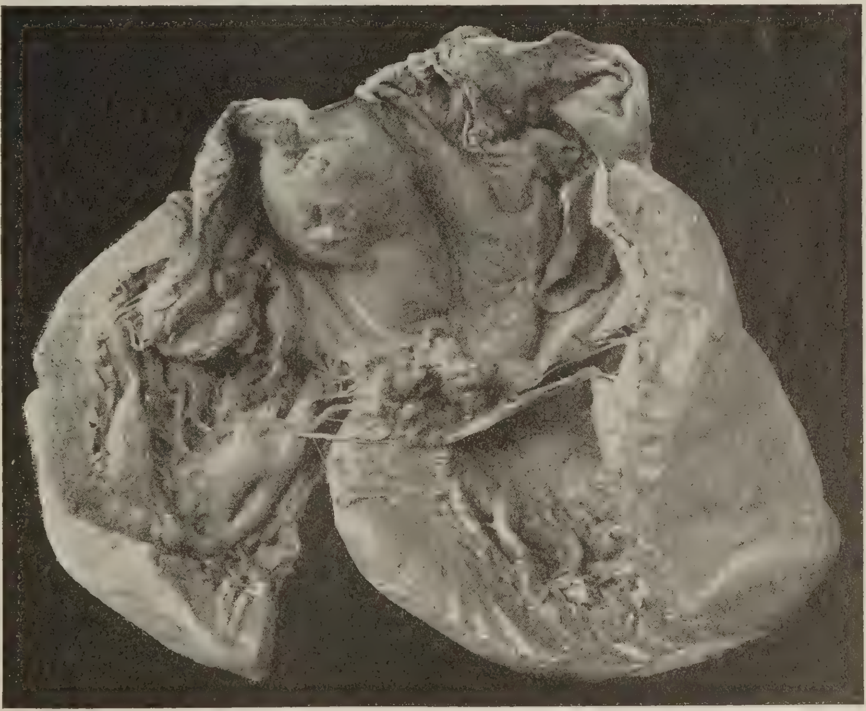

Fig. 2590.—Malignant Endocarditis Involving the Mitral Valves and the Left Auricle. (Original.)

Chorea seems to have a special association with endocarditis. The vast majority of fatal cases show endocarditis. During childhood scarlet fever is more often associated with endocarditis than any of the other diseases of early life. Thayer and Lazear have analyzed thirty cases of fatal ulcerative endocarditis which occurred in gonorrhœa.

Osler has demonstrated the frequent association of pneumonia with malignant endocarditis. Infected wounds, or septic processes, external or internal, such as puerperal fever, boils, gastric ulcer and bone necrosis may also be followed by the malignant variety. The infectious agent may find an entrance through lesions of the skin, mucous membranes of the throat, gastro-intestinal, respiratory, and genito-urinary tracts—and produce endocarditis.

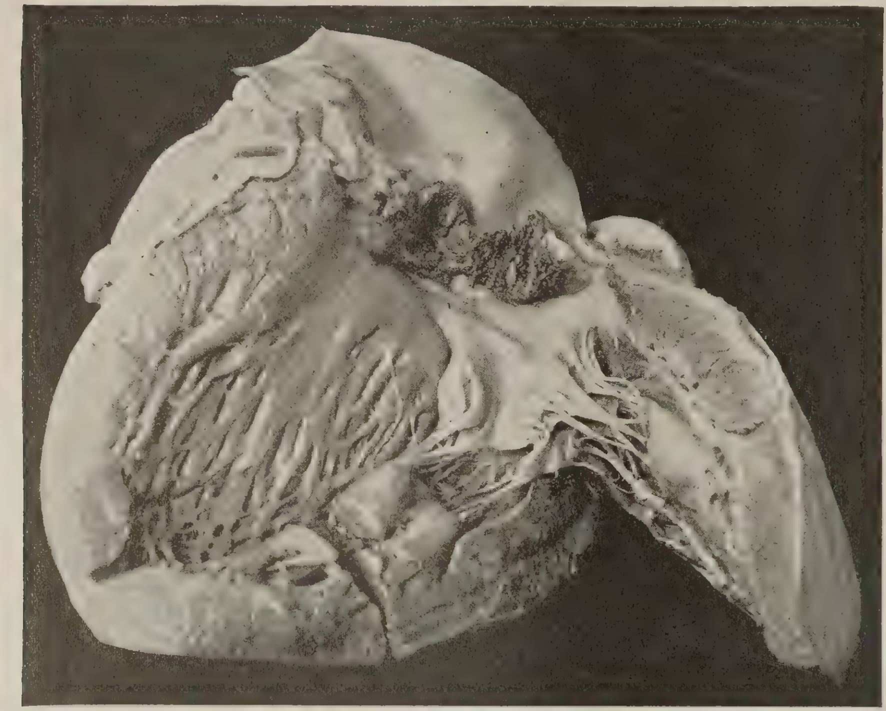

FIG. 2591.—Malignant Endocarditis; Ulceration of the Aortic Valves; Hole through One of the Valves; Old Atheroma. (Original.)

It is frequently found in debilitating diseases, such as Bright's disease, diabetes, cancer, etc. These diseases reduce the vitality of the patient, rendering him more susceptible to the action of the infectious agent.

Not many years ago in discussing the etiology of this disease a prominent authority wrote that it arose from exposure to cold or without any cause being discoverable. Our present certainty regarding its etiology is in pleasing contrast to former guesswork. Benign endocarditis is common to childhood. This is supposed to be due to the greater vulnerability to bacterial action during early life. The malignant form is rare in childhood.

MORBID ANATOMY.—*Benign Form.*—As a rule endocarditis involves the valves, but it is possible for it to be located upon the chordæ tendineæ, or the walls of the cavities (mural endocarditis). Grayish-yellow, opaque bodies, called vegetations, are seen upon the diseased valves, usually near their edges. They may be minute and in great numbers, may resemble venereal warts, or may be so large as to resemble an extensive cock's comb. Microscopically, they consist of a superficial layer of coagulated fibrin, in the upper layer of which are entangled numbers of leucocytes deposited from the blood stream. Deeper down is a layer of simple fibrin free from corpuscular elements and below this again is a layer of granulation tissue. In these vegetations bacteria are frequently found. Sometimes they are demonstrated only by culture methods. Again they are absent if the vegetation has existed for some time. These vegetations are a constant source of danger, as they are frequently whipped off by the blood current and carried as emboli to different parts of the body, producing striking symptoms. The mitral valves are most frequently attacked by this process. Next come the aortic and very infrequently the tricuspid and the pulmonary valves. Fœtal endocarditis is confined chiefly to the right side of the heart. The sequel of this morbid process may be resolution with no impairment of the function of the valve, or, more commonly, thickening, retraction, curling, or even calcification, resulting in chronic valvular lesions.

Malignant Form.—All stages of endocarditis are found from the benign through the transitional to the malignant form. The same bacteria are present in all, but are more numerous and virulent in the malignant. There is a deposit upon the inflamed area, resembling in many respects that of the benign form, but containing many bacteria of great virulence. If this becomes detached there is loss of tissue with the formation of an ulcer. This may penetrate both layers of the valve, or only one layer of the endocardium, thus producing a valvular aneurism. The destruction of tissue may be very rapid and extensive (Fig. 2592). As in the benign form, the left side of the heart is usually attacked. The tendinous cords, the wall, or the papillary muscles are more likely to be involved in the process than in the benign form. The changes produced by the bacterial emboli constitute an important part of the morbid anatomy of ulcerative endocarditis. Small masses of bacteria are whipped off by the blood current and are carried to the most diverse parts of the body: brain, lungs, kidneys, spleen, skin, mucous membranes, eye, etc. Inflammation and suppuration soon occur and we have the production of the so-called metastatic abscesses. Few of the viscera may escape.

SYMPTOMATOLOGY.—Flint truly says, authenticated cases of endocarditis disconnected from other diseases, which serve to mask its symptoms to a greater or less extent, are wanting.

Benign Form.—The symptoms are usually very indefinite, the patient rarely complaining of more than a præcordial distress. Almost never does this amount to an actual pain. There may be oppression and shortness of breath. The heart action may be rapid and irregular, furnishing symptoms of palpitation. The temperature is usually elevated as a result of the associated disease. A slight extra elevation, a degree or two, usually occurs with the advent of endocarditis. Naturally then, because of the unobtrusiveness of the symptoms, the disease is frequently latent and not recognized. The physician who keeps in mind the etiology of endocarditis and makes routine heart examinations in all cases of rheumatism, chorea, pneumonia, etc., most frequently recognizes the disease. It is extremely important to remember that in children and adolescents, a rheumatism followed by grave heart complications may be very insidious, and show itself only by a history of pain in joints or limbs—no appreciable swelling or tenderness of joints and very little fever.

The appearance of signs due to emboli frequently directs our attention to the heart.

Malignant Form.—In this variety we find grave constitutional symptoms. There are evidences of a most severe infection, which requires considerable skill in differential diagnosis. It may be impossible to separate the symptoms from those of the associated disease, such as sepsis or pneumonia. According to the symptomatology we distinguish two large classes: (1) The *typhoid*, in which the case resembles typhoid fever, showing continued fever, delirium, dry coated tongue, distended abdomen, roseola, splenic enlargement, and possibly diarrhœa. (2) The *septic*, resembling septicæmia. The temperature shows the streptococcus curve, *i.e.*, rapid elevation and descent several times daily, accompanied by chills and drenching sweats. There is profound intoxication and depression of vitality. The intermittent temperature and chills may suggest to some malaria. In these cases infective embolic processes are common, showing themselves in the skin, the mucous membrane, retina, and the various internal organs.

Certain authors mention a *cardiac* group in which patients with chronic valvular endocarditis show marked fever and evidences of recent endocarditis. Many of these cases resemble either the typhoid or the septic form and may run a very acute course. Others run a chronic course lasting for a year or so.

Another group of cases may be termed the *cerebral* in which the symptoms resemble meningitis, either basilar or cerebro-spinal.

Some authors also made a *cutaneous* group. Here petechial rashes are found; also skin abscesses from infected emboli. Erythematous rashes are not uncommon. Because of petechial rashes, cases of malignant endocarditis have been diagnosed cerebro-spinal meningitis and black smallpox.

Differential Diagnosis.—Attention to etiology will assist one. Benign endocarditis is more likely to follow rheumatism; malignant, infective processes and pneumonia. The symptoms of the malignant form are much more intense, suggesting septicæmia or typhoid fever. The positive Widal reaction, the absence of leucocytosis, the presence of the diazo reaction, would all point to typhoid fever. Unfortunately the Widal and diazo reactions may both be absent, and with the advent of a complication there may be a leucocytosis. So in some cases it is impossible to differentiate endocarditis from typhoid fever. Even a past master in the art of diagnosis like Osler diagnosed a case typhoid fever, which post mortem was proven to be endocarditis.

Osler gives the following points for guidance: The more abrupt onset in endocarditis, and the absence of any regularity of the pyrexia in the early stage of the disease, the cardiac pain, oppression, and shortness of breath may be early symptoms in malignant endocarditis. Rigors, too, are not uncommon. There is marked leucocytosis in infective endocarditis. Bacteriological examination of the blood as used by Cole of Johns Hopkins in the diagnosis of typhoid fever is of striking value, but unfortunately its field of application is limited. The specific variety of endocarditis has been diagnosed during life by the finding of the micro-organism in the blood.

Physical Signs.—These are very uncertain, because our main dependence is placed upon the presence of a soft blowing systolic murmur at the aortic or mitral areas. Such murmurs are extremely common and frequently do not mean endocarditis, but occur with the various acute febrile processes. Similar murmurs occur in anæmia, and in many conditions which cannot be explained. The size of the heart is not always of help to us, since an acute endocarditis may not enlarge it. If in the course of an acute disease a murmur develops under our observation, which cannot be accounted for by anæmia or weakness of the heart wall, and especially if accompanied by an increase in the fever, we are justified in diagnosing endocarditis. Sudden appearance and disappearance of murmurs may occur when vegetations are rapidly forming and changing their shape.

Prognosis.—In the vast majority of cases simple endocarditis entails no immediate danger. The danger in such cases is more or less remote and dependent upon the chronic valvular defects which follow.

Malignant Endocarditis.—Death may take place in three days. The disease may be protracted for months. Death results from progressive failure of strength or in consequence of secondary suppuration, or of embolism of an important cerebral vessel. The prognosis is almost always unfavorable.

Treatment.—This should combine treatment of the associated disease and the endocarditis. It will in most cases be necessary to treat the endocarditis after the patient has recovered from the associated pneumonia, rheu-

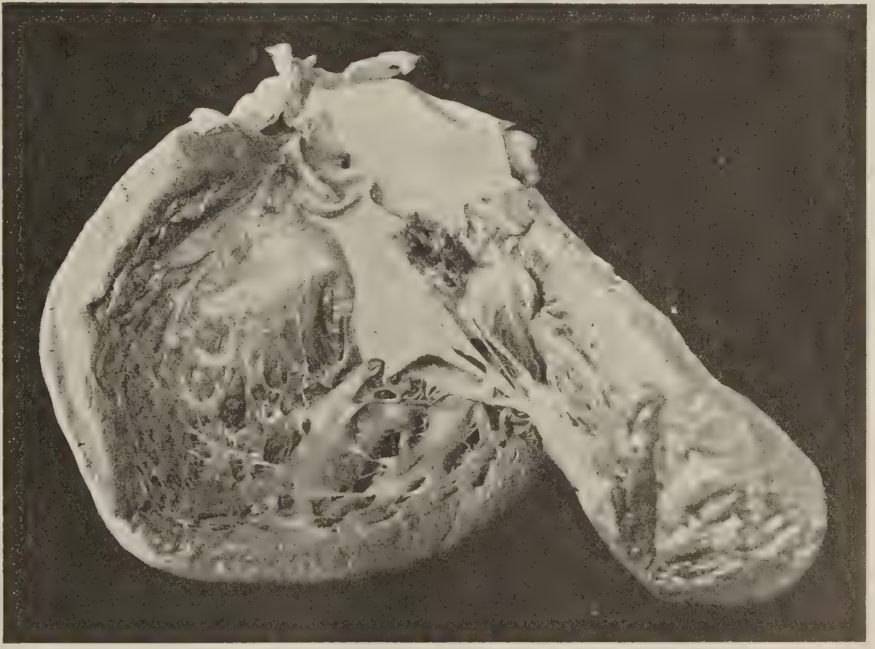

Fig. 2592.—Malignant Endocarditis; Destruction of Aortic Leaflet; Old Thickening of Aortic Valves; Dilatation of the Left Ventricle. (Original.)

matism, etc. Whether the salicylates have any effect upon endocarditis is a much mooted question. I am of the opinion that they have a decided indirect effect upon the valvular disease. Any one who has administered salicylates in proper dosage in acute articular rheumatism knows of their remarkable, almost specific control over the disease. Endocarditis may develop at any time during the progress of a rheumatic fever; consequently if we shorten the time of the disease we lessen the possibility of the development of endocarditis. If the valvular inflammation has already developed, the chances of resolution are increased, if the fever, pain, and restlessness are controlled by the giving of the salicyl compounds. Bruce advises the combination of digitalis with the salicylates if the heart seems weak. In the direct treatment of endocarditis *rest* is by all means the most essential thing. The work of the heart and the movement of the diseased valves must be reduced to a minimum. This is the best accomplished by putting the patient to bed. An ice bag over the præcordium is often of service in quieting the action of the heart. The time required in bed must be decided by the progress of the case. It may require months in order to guard against serious and permanent injury to the heart. At best this frequently cannot be avoided. The development of symptoms of incompensation will demand the administration of digitalis and strychnine. Anæmia frequently develops as the disease progresses, and requires iron, tonics, good food, and fresh air. Mercuric chloride and quinine have been employed in ulcerative endocarditis for the purpose of destroying the bacteria upon the endocardium, but it is very unlikely that they are of any use.

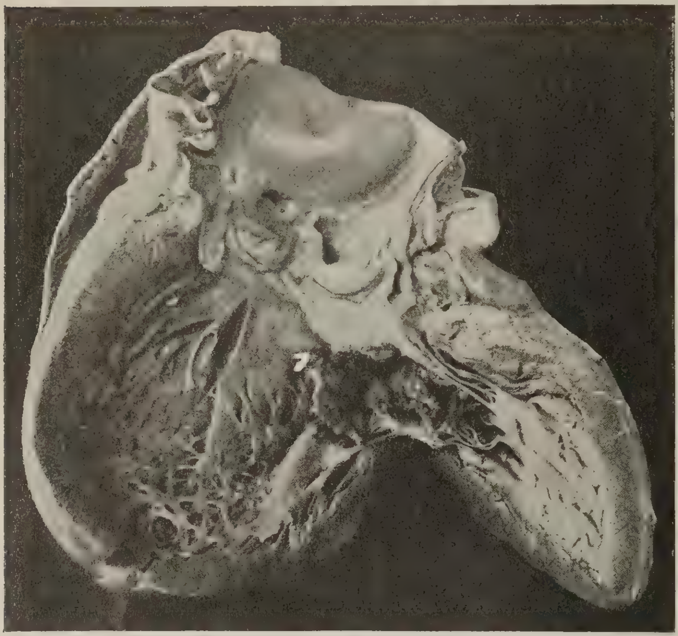

FIG. 2593.—Malignant Endocarditis on Top of Old Sclerosing Process. Marked Involvement of the mitral valves. (Original.)

ACUTE RECURRENT ENDOCARDITIS is a very interesting form occurring on old valve lesions. It may be benign or malignant (Fig. 2593).

CHRONIC ENDOCARDITIS is either a sequel of the acute form or is an evidence of senility, being a part of the process of arteriosclerosis, involving the general arterial system. This contracting endocarditis leads to thickening, curling, contraction, and frequently to calcification of the valves. The same causes which produce premature arteriosclerosis produce it, namely: excessive physical activity, excessive use of alcohol, syphilis, gout and diabetes, and chronic diseases of the kidneys. The chordæ tendineæ may gradually become shortened, greatly thickened, and in extreme cases the papillary muscles are implanted directly upon the sclerotic and deformed valves.

The effects and treatment of chronic endocarditis are those of chronic valvular lesions and will be considered under that heading. *James Rae Arneill.*

HEART DISEASES: FATTY DEGENERATION.

—Fatty degeneration of the heart muscle is a retrograde change characterized by the formation of minute fat droplets within the muscle protoplasm. It is distinguished from fatty infiltration, in that in the latter process the fat is deposited in connective-tissue cells, either beneath the pericardium or between the muscle fibres. The term *fat heart* is often used as a designation for both fatty degeneration and infiltration, but it should be applied to the latter condition only. It should be emphasized that the essential difference between these two conditions is, that in fatty degeneration the fat is in the muscle cell, formed there by the disorganization of the muscle protoplasm; while in fatty infiltration the fat is in connective-tissue cells, deposited there from the blood.

GROSS APPEARANCES.—Severe degrees of fatty degeneration may exist without recognizable changes in the appearance of the heart. The naked-eye diagnosis of this condition is in many cases difficult and uncertain. When the process is extreme the heart muscle becomes yellowish in color, and of softer consistence; it may have a fatty shine or give a fatty smear. The condition may be diffuse or localized to certain areas. The latter form is the more readily diagnosed, inasmuch as the heart muscle so affected presents a peculiar mottling of red and yellow, occasionally disposed in the form of stripes or broken bars, the so-called "tiger-heart." This appearance is best seen on the endocardial surface of the left ventricle. In the majority of cases the degeneration is most marked in the wall of the left ventricle near the apex; the septum, right ventricle and auricles being affected in degree according to the order given. In the left ventricle the papillary muscles and trabeculæ usually show the most severe change, and in some cases the process may be sharply localized to these, the yellowish color of the papillary muscles standing out in sharp contrast to the normal brownish-red of the remainder of the heart wall. The heart is usually increased in size without a corresponding increase of weight. Dilatation of greater or less degree occurs, and the organ as a whole is flabby, flattening when laid upon the table. On section into the muscle the color change may affect the wall uniformly throughout, but more often it is found in streaks and patches of varying form, size, and distribution. The discolored muscle is more opaque than normal, cloudy, easily torn, and gives a fatty smear to a warm knife. In very extreme cases the degeneration may be so severe in sharply outlined areas as to present an appearance closely resembling that of an abscess. It must be remembered that fatty degeneration of the heart muscle rarely exists alone, but is usually associated with cloudy swelling, atrophy, anæmia, etc., all of which processes complicate the diagnosis from the gross appearances.

MICROSCOPICAL APPEARANCES.—The diagnosis of fatty degeneration in many cases can be made only on microscopical examination. This should always be done with the fresh tissue when possible, inasmuch as the processes of fixation and hardening often completely destroy the appearances of the degeneration by the removal of the fat droplets and the contraction of the tissue. Fixation of the muscle in osmic acid or Flemming's solution will obviate this danger. Slight degrees of fatty change are, however, always best brought out by the treatment of freshly teased muscle with osmic acid. The affected muscle fibres are found to contain minute fat-droplets arranged in rows between the masses of interfibrillary sarcoplasm, beginning about the nucleus and extending linearly toward the ends of the fibres. In the early stages the transverse striations are usually not affected, but in severe degrees of the change they gradually disappear, first at the fibre-ends and then toward the nuclei. The staining power of the nucleus is always affected; in extreme degrees the nuclei may be entirely lost. The changes are usually most marked in the fibres lying just beneath the endo- and pericardium, the endocardium itself being rarely affected. In the acute forms of fatty degeneration cloudy swelling, segmentation, and fragmentation, etc., are usually found in association with the fatty change; in the chronic cases atrophy of the fibres, both simple and pigment, with increase of the interstitial connective tissue, is present.

Etiology.—The causes of fatty degeneration of the heart are both local and general. Of the former disturbed nutrition resulting from sclerosis or obstruction of the coronary arteries is the most common and important cause. Fatty degeneration of the muscle may also be caused by disturbances of nutrition secondary to myocarditis, cardiac abscess, pericarditis, and endocarditis. In pericarditis the degeneration may be confined to the layer of muscle immediately beneath the epicardium.

The two great general causes of this degeneration are anæmia and intoxication. It is of common occurrence in pernicious anæmia, chlorosis, leukæmia, and all forms of secondary anæmia. It occurs after long-continued or frequently repeated hemorrhage (epistaxis, hæmoptysis, hæmatemesis, menorrhagia, metrorrhagia, hemorrhage from the intestines, hæmaturia, etc.). It has been observed after venesection. Fatty degeneration is also commonly associated with the cachectic anæmias of chronic suppuration, chronic diarrhœas, syphilis, tuberculosis, malaria, malignant growths, etc. In all of these conditions the systemic intoxication is to be regarded also as a possible factor in the production of the condition. Deficient oxygenation due to cardiac insufficiency, valvular lesions, emphysema, fibroid pneumonia, etc., also causes fatty change of the heart muscle. The relation of fatty degeneration to cardiac insufficiency is not entirely clear; the condition is almost always present in the failure of compensation of the hypertrophied heart in chronic valvular disease, and while it is usually regarded as being the cause it is also possible that it may be the result of the cardiac insufficiency.

Extreme fatty degeneration of the cardiac muscle occurs in poisoning with phosphorus, arsenic, antimony, etc. It may also occur to an extensive degree in the acute infectious diseases, especially in typhus and typhoid fevers, recurrent fever, scarlet fever, diphtheria, pneumonia, puerperal fever, pyæmia, etc. In acute yellow atrophy of the liver and in puerperal eclampsia the fatty degeneration of the heart may be so marked as to resemble that seen in phosphorus poisoning. In the infectious diseases the fatty change is to be attributed chiefly to the action of the poisons produced in these conditions, but the effect of the increased temperature of the body must also be regarded as an important factor. Long-continued mercurial inunctions, iodoform and chloroform poisoning, morphinism, the camphor habit, the long-continued use of dilute mineral acids in beverages, or as adulterants of vinegar, mushroom poisoning, etc., are among the many other supposed factors of fatty degeneration of the myocardium. In the later stages of chronic nephritis and gout there is almost always present extensive fatty change in the heart, resulting partly from the general cachexia and anæmia, and partly from sclerotic changes in the coronary vessels. The habitual use of alcohol is one of the most important causes of slowly progressive fatty degeneration of the myocardium. The condition is found particularly in the case of habitual beer drinkers. The condition is of very frequent occurrence among the lower classes in Germany and Austria with whom beer forms a very important part of the daily diet. In France the use of dilute mineral acids in some of the beverages consumed by the lower classes is said to be an important factor in the production of fatty degeneration.

High living, over-eating, lack of exercise as well as excessive muscular activity are regarded as either primary or predisposing factors to cardiac degeneration. Idiopathic hypertrophy is practically always followed by fatty degeneration. Cardiac over-strain in laborers, athletes, etc., is another very important etiological factor. A slight amount of fatty change in the senile heart is to be regarded as physiological. The pathological fatty degeneration of the heart due to anæmia or cachexia is found more frequently in women than in males; that due to coronary sclerosis, alcoholism, etc., much more frequently in males. The majority of the cases are in individuals past fifty years of age. Cardiac fatty degeneration occurring in young individuals is almost always due to intoxication or infection.

Symptoms.—The symptoms of fatty degeneration do not differ from those of other forms of myocardial affections. It is usually impossible to differentiate between fatty and fibroid heart. The most extreme degrees of fatty degeneration, as found in severe cachexias, pernicious anæmia, etc., may give rise to no symptoms if cardiac dilatation has not taken place. It is the latter condition which produces the symptoms which are usually associated with fatty degeneration. Dyspnœa, cardiac irregularity, palpitation, præcordial distress, vertigo, the so-called pseudo-apoplectic attacks, rapid and weak pulse, etc., are symptoms of dilatation rather than of fatty degeneration. Very rarely anginal attacks may occur without coronary changes. In the late stages Cheyne-Stokes breathing may be present. The physical signs are those of dilatation. Death may occur from sudden over-strain or from slowly developing cardiac insufficiency. In rare cases aneurismal dilatation of the cardiac wall may result from local weakening of the myocardium due to fatty degeneration.

Prognosis.—In the majority of cases of myocardial disease the prognosis is very unfavorable, especially in the slowly developing or chronic form. Acute degeneration of mild degree caused by acute infections or poisoning may recover completely; the more severe forms may be very quickly fatal. Within certain limits chronic fatty change of mild degree does not quickly lead to a fatal issue.

Treatment.—The occurrence of fatty degeneration may be many times prevented by careful regulation of the daily life. In suspected cases strict diet should be enforced, the amount and character of muscular activity carefully planned, and the patient protected from excitement of all kinds. Sudden death during sexual intercourse, straining at stool, lifting, running, etc., is extremely common in this affection. Alcohol should be entirely withdrawn, and the amount of fluid limited. When the signs of dilatation have not appeared digitalis is usually not advisable. Strychnine and nitroglycerin may be given. When symptoms of cardiac insufficiency are present the treatment should be carried out along the lines indicated for the treatment of failure of compensation in chronic valvular disease.

Aldred Scott Warthin.

HEART DISEASES: FATTY INFILTRATION.—Fatty infiltration of the heart is that condition in which the subepicardial fat alone is greatly increased, or in connection with this increase there is also an extension of adipose tissue into the myocardium. Normally there should be but a small amount of subepicardial fat and this should be confined to the sulci and grooves along the superficial coronary vessels, being greatest in amount at the base of the heart. Over the greater part of the ventricular surfaces in the active, muscular male of early adult life there should be no fat, but after the age of forty there is a physiological increase in the amount of the cardiac panniculus. There are, however, wide individual variations in the amount of subepicardial fat within apparently normal limits, depending upon intrinsic peculiarities of metabolism, habits of life, etc. The presence of fat cells between the muscle fibres in the interstitial tissue of the myocardium is under all circumstances to be regarded as pathological. Such an encroachment upon the muscle is usually due to a direct extension of adipose tissue from the subepicardial fat, chiefly along the lines of the arterial branches. Secondary to the infiltration of adipose tissue there is an atrophy of the heart muscle. In extreme cases the greater part of the myocardium may be replaced by adipose tissue which may extend even to the endocardium. In some cases the deposit of fat in the cells of the interstitial tissue may be secondary to a primary atrophy or degeneration of the heart muscle, the formation of fatty tissue being of the nature of a compensatory process. Two forms of fatty infiltration may therefore be distinguished clinically: primary and secondary fatty heart. Of these the first variety is by far the most common and important.

In extensive hyperplasia of the subepicardial panniculus the heart is usually increased in size, partly from increased thickness of its wall, and partly from dilatation. The weight of the organ may or may not be above that of the normal. The entire heart may be encased in a thick layer of fat (lipoma capsulare cordis, obesitas cordis, lipomatosis cordis, fatty overgrowth, Mastfettherz, etc.). The most extensive deposit is found at the base of the ventricles along the auriculo-ventricular groove, in some cases having a distinct lobular arrangement. The heart muscle may not be visible through the epicardium at any point. On section through the heart the layer of adipose tissue may be found to form almost the entire thickness of the wall, the muscle consisting of a thin layer beneath the endocardium. In the most extreme cases the fat may reach to the endocardium in the form of trabeculæ extending along the intermuscular septa, gradually diminishing in size as they approach the endocardium. On microscopical examination groups of fat cells are seen between the muscle fibres. The latter may show varying stages of simple or pigment atrophy. Fatty degeneration of the atrophic muscle is not infrequently present.

Fatty infiltration of the heart may exist as a part of a general obesity, either congenital or acquired. Lack of exercise, over-eating, excessive use of carbohydrates, alcohol, etc., as well as excessive water drinking are the most important factors in the production of this condition. It is most common in males at middle age; in women it may exist as a part of general obesity associated with or following the menopause. Deficient oxygenation from anæmia or from chronic pulmonary disease also leads frequently to fatty infiltration of the heart. The condition is often found in the cachexias of chronic tuberculosis, carcinoma, etc. It occurs in the early stage of diabetes, and in certain forms of chronic poisoning, drug habits, etc. (iodoform, morphine, camphor, chloroform, dilute mineral acids, etc.).

A moderate degree of fatty infiltration may exist without signs or symptoms, but beyond a certain limit the over-accumulation of fat beneath the epicardium or its infiltration into the myocardium causes impairment of the cardiac function. In such cases the apex beat is lost, the cardiac impulse is very faint or not present at all, the area of dulness is increased, and the heart sounds are muffled. The pulse is soft, of low tension, often rapid and irregular. The affected individual is stout, with excessive abdominal panniculus, and usually shows signs of general venous congestion. Palpitation, præcordial distress, and dyspnœa are produced by slight exertion, and there is a tendency to excessive sweating. The urine is usually increased in amount, pale and of a low specific gravity. In an individual with general obesity these signs and symptoms may be taken as certain indications of fatty heart. In the cases of primary atrophy of the heart muscle with secondary fatty infiltration the differential diagnosis is not so easily made. In these cases the subcutaneous panniculus may be greatly decreased, and the cardiac symptoms obscured by those of the condition causing the myocardial atrophy. In the later stages of fatty infiltration the symptoms are those of cardiac dilatation, and the condition cannot be diagnosed from other forms of myocardial affections.

The prognosis on the whole is much more favorable than in the case of fatty degeneration. In cases of acquired obesity due to manner of living it is quite good. In congenital obesity it is much less favorable, and when secondary to other disease processes the prognosis rests wholly upon that of the more serious condition. It must be emphasized that the individual with fatty heart cannot meet without danger many conditions involving slight degrees of heart-strain. Intercurrent affections such as influenza, bronchitis, pneumonia, typhoid fever, etc., are very likely to cause death through cardiac insufficiency. Anæsthesia, surgical operations, excessive fatigue, muscular strain, intense emotion, etc., are to be regarded as dangerous factors in the case of individuals affected with fatty infiltration. While sudden death is not infrequent in this condition it is not nearly so common as in the case of fatty degeneration.

In the cases associated with obesity the treatment is very simple and if carefully followed very successful. The administration of drugs is of secondary importance and is usually limited to general tonics and to the improvement of elimination. The essential factors of the treatment are entirely hygienic. The diet should be chiefly nitrogenous, fats and carbohydrates being reduced to the smallest possible proportions. The use of alcohol should be entirely stopped, and but little fluid should be taken with the meals. The quantity of food and drink taken should be most carefully regulated. The amount and character of physical exercise taken are of prime importance and should be most carefully prescribed. The use of certain mineral waters is of great value in many cases as a means of promoting elimination. Turkish baths may be employed toward the same end. In the forms of fatty infiltration due to anæmia, etc., the treatment is carried out along lines depending upon the primary disease. *Aldred Scott Warthin.*

HEART DISEASES: FIBROID HEART.—The terms cardio-sclerosis and chronic fibrous myocarditis are synonyms. There is either a hyperplasia of interstitial connective tissue, or a replacement of heart muscle, more or less extensive, by fibrous tissue.

Etiology.—It is intimately associated in most instances with the process of arterio-sclerosis, especially in its involvement of the coronary arteries. The blocking of one of these arteries by a thrombus or an embolus leads to a condition termed anæmic necrosis, or white infarct. Fibrous myocarditis may result from the gradual transformation of such processes into fibrous tissue. It frequently follows the narrowing of a coronary branch in the process of obliterative endarteritis. According to Broadbent, syphilitic disease of the myocardium and chronic interstitial myocarditis in association with subacute pericarditis and adherent pericardium, are the commonest causes of diffuse interstitial fibrosis. Chronic nephritis, with associated high tension in the arterial system, produces thickening in the walls of the arterioles, and increase of connective tissue in their proximity. Chronic alcoholism may be associated with a diffuse fibroid infiltration. Myocarditic cicatrices may sometimes result from a previous pericarditis or endocarditis, the inflammation extending through to the heart muscle.

Morbid Anatomy.—This sclerosis occurs most frequently at the apex of the left ventricle and in the septum, but may occur in any portion. In the septum there are often streaks of fibroid degeneration which do not reach the endocardium; it may be necessary to divide the muscle in order to see them. This degeneration is the invariable precursor of aneurism of the heart.

Symptoms.—It occurs in men past middle life. The symptoms are extremely unreliable. The so-called classical symptoms are just as likely not to be present. In rare cases the pulse may be infrequent, even as low as 26; there may be shortness of breath and œdema. In other cases we may find a rapid, irregular, and unequal pulse, with signs of incompensation. Those cases in which coronary arterio-sclerosis is present frequently show symptoms of angina pectoris.

Physical signs are very indefinite. There may be some hypertrophy. Murmurs, systolic in time, may be present during incompensation. The sounds may be weak, irregular, and valvular in character; accentuation of the aortic second, and reduplication of some of the sounds, a diffuse slapping cardiac impulse, and even a gallop rhythm may be present. Post-mortem examination has proven the unreliability of symptoms and physical signs in the diagnosis of this condition, even in the hands of experts. Cabot states that a prominent Boston pathologist told him he had never seen a case of myocarditis correctly diagnosed. So far as symptoms and signs go it is impossible to distinguish the fibroid from the fatty heart. My observation is that physicians usually diagnose fatty heart if the patient is obese, fibroid heart if he is lean.

COURSE OF DISEASE.—These patients may die suddenly without having previously shown any symptoms; there may be rupture of the heart or a blocking of a coronary artery. Again, they may present symptoms exactly similar to those of an incompensated valvular lesion. Dilatation of the cavities with the development of murmurs of relative insufficiency make it impossible to distinguish it from valvular lesions.

PROGNOSIS.—It is distinctly unfavorable except in syphilitic cases, which may respond promptly to the use of iodides.

TREATMENT.—Appreciating the uncertainty of a diagnosis, our treatment of suspected cases must be based upon the broad lines of common sense and must depend mostly upon indications drawn from the symptoms and signs of weak heart. If symptoms of incompensation are present, the patient must be put to bed and placed upon digitalis and strychnine, with a light, nutritious diet. As routine measures these patients should observe moderation in food and drink, and avoid variations in blood pressure by a very even life; the bowels should be kept open with mild mercurials and saline purgatives. Strychnine, gr. $\frac{1}{30}$, every six hours, or in the form of nux vomica, gtt. xx. three or four times daily, is useful. If arterial tension is high, nitroglycerin is indicated.

James Rae Arneill.

HEART DISEASES: HYPERTROPHY AND DILATATION.—A discussion of these pathological conditions under a separate heading necessitates more or less repetition of facts stated in the articles on valvular and myocardial diseases.

These conditions usually go hand-in-hand; at times the hypertrophy exceeds the dilatation, at other times the dilatation exceeds the hypertrophy. It is very unusual to find a pure hypertrophy or a pure dilatation.

Hypertrophy is almost invariably a conservative process; *dilatation* on the other hand, though at times conservative, as in aortic insufficiency, is generally destructive. Both conditions may affect the whole heart, but are more likely to be limited to one part. We may even have hypertrophy limited to one papillary muscle and dilatation to a conus arteriosus.

Hypertrophy means an increase in the mass of muscular tissue, usually associated with an increase in volume. *Dilatation* means an enlargement of the cavities of the heart. The same laws which affect the development of muscular tissue in other parts of the body apply to the heart. Under conditions of proper nutrition, increased work causes an enlargement of the cardiac muscle. Ziegler says this increase in size takes place by enlargement of the muscle cells. Whether or not a proliferation of the cells also is present is not yet positively known. Some authorities believe there is a definite increase in the number of muscle cells.

Schroetter divides hypertrophy into three classes:

I. Simple hypertrophy,—increase of the heart in volume with normal cavities.

II. Concentric hypertrophy,—thickening of the walls with diminution in the size of cavities.

III. Excentric hypertrophy,—increase in muscular tissue, with enlargement of cavities.

Of these three classes only the third, excentric hypertrophy, is of special interest to us. The first two divisions are comparatively rare.

If work above its normal capacity is thrown upon any part of the heart, hypertrophy results. This is brought about by the presence of unusual obstruction to the flow of blood, and by excessive stimulation of the nervous mechanism of the heart.

Let us now consider in some detail the different causes which produce hypertrophy of special portions of the heart:

Left Ventricle.—The following are the conditions under which hypertrophy of this part takes place:

(*a*) Valvular lesions: Aortic insufficiency, aortic stenosis, mitral insufficiency; (*b*) the various conditions which cause increased resistance in the greater circulation, namely: aneurism, congenital narrowing of the aorta (rare), small arterial system (rare), arterio-sclerosis (very common) in which there may be both diminution in the calibre of the artery and loss of elasticity. The elasticity of the arterial wall is a powerful aid in propelling the blood current forward. Various intoxications cause a contraction of the peripheral circulation and thus raise blood pressure. Chief among these are the various forms of Bright's disease; also gout and lead poisoning. With these diseases, especially chronic interstitial nephritis, we frequently find a high grade of arterio-sclerosis. The entire heart may become involved in this hypertrophy. At present I have under observation a middle-aged patient who shows considerable cardiac hypertrophy, the apex being in the anterior axillary line. Valvular lesions have never been demonstrated in this case; there is, however, considerable arterio-sclerosis.

The excessive use of tea, coffee, alcohol, and tobacco, through their exciting action on the nervous mechanism of the heart, may produce slight hypertrophy. Exophthalmic goitre and various nervous conditions, such as neurasthenia, if of sufficient duration, may cause hypertrophy. But valvular lesions are a frequent complication of Graves' disease.

(*c*) Pathological conditions in the heart wall, such as chronic myocarditis and adherent pericardium, give rise to hypertrophy, because of the obstruction offered to the orderly and regular contractions of the heart.

Right Ventricle.—It is hypertrophied under the following conditions:

(*a*) Valvular lesions; most frequently, mitral insufficiency, and stenosis; the very rare lesions of the right heart, pulmonary stenosis and insufficiency, tricuspid stenosis and insufficiency. Relative tricuspid insufficiency secondary to left heart lesions is rather frequent.

(*b*) Increased resistance in the pulmonary circulation, due to narrowing of the calibre of the pulmonary artery by pressure from without, as by aneurism, tumors, and so forth; congenital narrowing and arterio-sclerosis of the pulmonary artery (rare); also the cutting off of capillary regions in the lungs by pleurisy, pneumothorax if of sufficient duration, chronic fibroid conditions, tumors, chronic infiltrations with or without cavities, *emphysema*, spinal curvature with dislocation of the heart.

Auricles.—Hypertrophy of these chambers is much rarer than dilatation, and is usually associated with a much greater degree of dilatation. The left auricle hypertrophies more than the right.

Hypertrophy of the whole heart takes place when there is a combination of several causes, for instance, aortic and mitral insufficiencies, combined with a relative tricuspid insufficiency; of valvular disease complicated by lung or arterial disease.

Athletic Heart.—Allbutt and Stengel have made special studies of the athletic heart among the students of Cambridge and the University of Pennsylvania. They have demonstrated by means of percussion and location of the apex, that several years of the severer forms of athletics, such as distance running, rowing and football, will increase the size of the heart considerably. In these cases the valves are healthy. It is true that in some instances a so-called athlete's heart is one enlarged by aortic or mitral insufficiency. Seitz in Germany, and Da Costa in this country, have called our attention to a very similar condition in soldiers who have undergone severe strain from long marches.

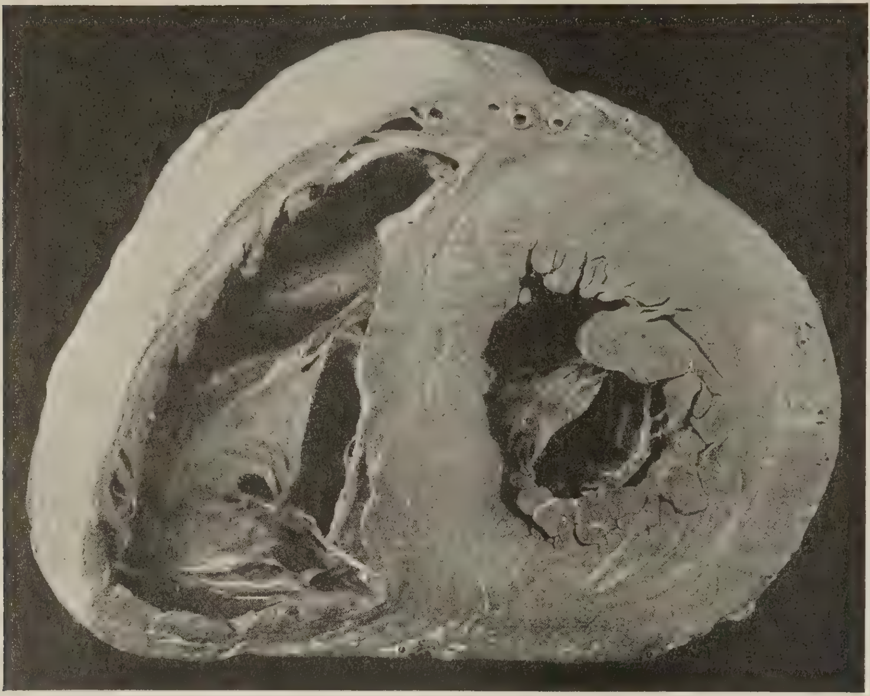

FIG. 2594.—Hypertrophy of the Left Ventricle and Dilatation of the Right. (Original.)

Morbid Anatomy.—The size of the average normal heart is about equal to the patient's closed right fist. The heart of the adult male weighs about nine ounces; of the female eight ounces. The majority of hypertrophied hearts weigh from sixteen to twenty ounces. Hearts of enormous size have been reported; Beverley Robinson has reported a heart weighing fifty-three ounces, Alonzo Clark one weighing fifty-seven ounces, and Stokes one weighing sixty-four ounces. Another good method of determining the extent of hypertrophy is by measuring the thickness of the wall after the heart has been thoroughly relaxed by soaking in water. The left ventricle normally has a thickness of 9 to 12 mm.; so a thickness of 20 to 25 mm. indicates hypertrophy. The right ventricle is thinner than the left, measuring on an average 4 to 7 mm. When hypertrophied it measures from 13 to 20 mm. The left auricle has a normal thickness of about 3 mm.; the right scarcely 2 mm. The auricles may be doubled in thickness when hypertrophied.

The conical shape of the heart is lost in hypertrophy and dilatation, by reason of the apex being greatly broadened and rounded. When the right ventricle is chiefly affected it occupies most of the apex. The hypertrophied muscle is deep red in color and firmer than the normal heart.

Dilatation. — Schroetter divides it into three classes:

I. Simple dilatation,—enlargement of cavities with normal thickness of the walls.

II. Active dilatation, —enlargement of the cavities of the heart with increased thickness of the walls, *i.e.*, excentric hypertrophy.

III. Passive dilatation, — enlargement of the cavities with thinning of their walls.

Active and passive dilatation are of special interest. The former has been discussed under its synonym, excentric hypertrophy.

Dilatation is always a secondary process and is due either to (*a*) increase of pressure within a cavity whose walls are not hypertrophied, or (*b*) normal pressure

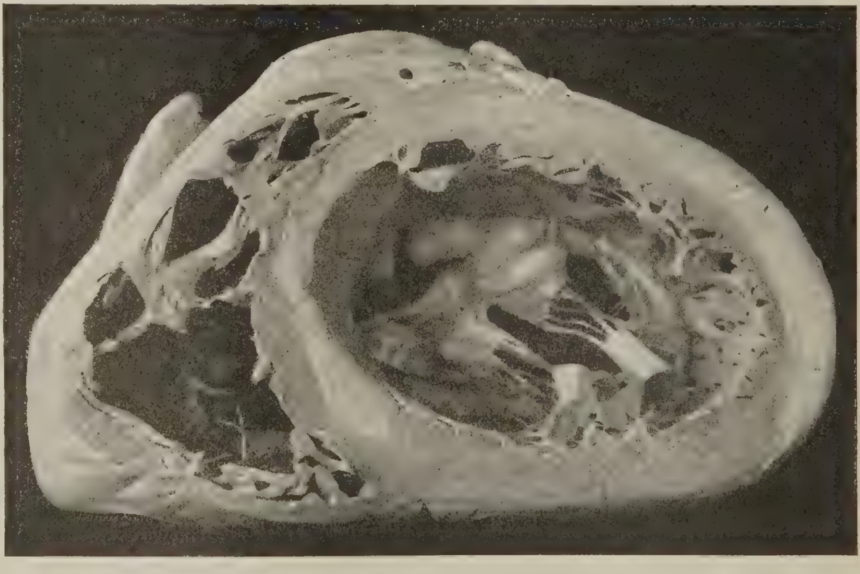

FIG. 2595.—Dilatation Involving Both Sides of the Heart. (Original.)

within cavities whose walls have been weakened by myocardial disease. Aortic insufficiency offers the best illustration of the first class. In it the dilatation of the left ventricle is due to the chamber being filled from two sides at once, the blood from the left auricle and that which regurgitates from the aorta. As a result of the increased pressure the ventricle yields. Soon hypertrophy develops, producing a typical example of excentric hypertrophy. Whether dilatation or hypertrophy will prevail depends on the nature and quality of the heart tissue.

When the capillary circulation of the lungs is overdistended, as it may be in mitral insufficiency and stenosis, the right heart meets an unusual resistance in discharging its blood into the pulmonary artery. This back pressure, together with the pressure of the blood which normally enters the ventricle from the right auricle, causes dilatation, and just so much sooner on this side than on the other, as the right ventricle is weaker than the left.

Pulmonary insufficiency and tricuspid insufficiency also cause dilatation of the right ventricle. Diseases of the lungs and pleura, especially if associated with myocardiac disease, as in lobar pneumonia, may cause a fatal dilatation of the right heart. Emphysema is usually associated with dilatation of the right ventricle.

The auricles are prone to extensive dilatation, not having muscular tissue enough for the development of much hypertrophy. The left auricle dilates in mitral insufficiency and stenosis, the right in tricuspid insufficiency and stenosis. The development of relative insufficiency of the auriculo-ventricular valves from dilatation of the ventricles, is a frequent cause of dilatation of the auricles. When incompensation develops in the course of the various heart lesions, marked dilatation of all the cavities is likely to follow.

Morbid Anatomy.—The cavities may be vastly increased in size, even trebled in capacity. The auricles may contain from eighteen to twenty ounces of blood. The auriculo-ventricular rings may be greatly dilated. The mitral orifice, which normally has a circumference of about three and one-half inches, may be increased to five and one-half inches and more; the tricuspid orifice normally has a circumference of about four and one-half inches and may be increased to six inches. The bundles of muscle fibres may be greatly thinned and separated. In Figs. 2594 and 2595 there was marked separation of the bundles of muscle with only a thin semitransparent membrane between; the endocardium and epicardium were in places in apposition.

SYMPTOMS AND PHYSICAL SIGNS.—Very little space need be devoted to them as they have been considered in detail under valvular lesions of the heart.

The so-called idiopathic hypertrophy produces a strong first sound at the apex and an accentuated aortic second, unaccompanied by murmurs. Hypertrophy of the right ventricle, due to disease in the lungs and pleura, produces a strong first sound in the tricuspid area with an accentuated pulmonary second. The apex beat is heaving and dislocated to the left, and usually downward. The pulse is likely to be much stronger than in the hypertrophy due to valvular lesions. The forcible heart action may or may not be perceptible to the individual.

In dilatation the apex beat loses its heaving character, is diffuse, undulatory and irregular, and taps against the chest rather than thrusts; dulness increases, especially to right and left. The heart sounds become weak, the first approaching the second in its valvular character; if murmurs are present they become weak, or even may disappear; fatal gallop rhythm may develop. The pulse becomes small, irregular, and unequal. All of the classical symptoms of incompensation may develop, such as cyanosis, dyspnœa, œdema, bronchitis, gastro-intestinal disturbances, and marked nervousness.

The treatment of these conditions has been discussed in detail in the article devoted to valvular lesions of the heart. *James Rae Arneill.*

HEART DISEASES: MYOCARDITIS.

—Under this heading I shall discuss (1) Acute Interstitial Myocarditis, (2) Parenchymatous Degeneration of the Myocardium, (3) Segmentation and Fragmentation, (4) Abscess of the Heart.

I. *Acute Interstitial Myocarditis.*—This is a disease in which the intermuscular connective tissue is swollen and infiltrated with small round cells and leucocytes; the blood-vessels are dilated and the muscle fibres the seat of granular, fatty, and hyaline degeneration. Acute endocarditis and pericarditis, diphtheria and typhoid fever are most commonly associated with it. Councilman has described a very similar condition as a sequel of gonorrhœa and was able to demonstrate gonococci in the diseased areas.

II. *Parenchymatous Degeneration.*—This is extremely common because of its intimate association with the numerous acute infectious diseases and toxæmias. It varies much in degree, in most cases being mild. In practically all of the continued fevers the myocardium is affected, but not so much from the fever as from the associated toxæmia. It may develop in the course of a pericarditis or an endocarditis.

The heart is pale, turbid, and extremely soft. Microscopically there is granular degeneration of the muscle fibres. They may even lose their striæ. The sudden deaths which occasionally occur during the convalescence of diphtheria, pneumonia, typhoid fever and influenza, are undoubtedly dependent on the presence of a severe grade of parenchymatous degeneration. Acute dilatation of the heart develops very readily under these circumstances and explains the fatal termination.

The physical signs are those of cardiac weakness. The pulse is feeble and may be both irregular and unequal; the first sound at the apex becomes weaker and more valvular in character. Soft blowing systolic murmurs may develop especially in the pulmonary regions. The patient is weak and becomes short of breath on slight exertion.

III. *Fragmentation and Segmentation.*—These conditions of the heart muscle interest the pathologist rather than the clinician. Renaut and Landouzy first called direct attention to the dissociation of the muscle cells in 1877. Renaut has gone so far as to consider this condition a distinct disease from the clinician's standpoint. However, it seems to us impossible to attempt to distinguish with any degree of certainty this from numerous other diseases of the myocardium, by means of signs and symptoms. In segmentation there is a separation of fibres at the cement line. In fragmentation the fracture is across the fibre and perhaps at the level of the nucleus; longitudinal division is very rare. Such hearts are soft and easily torn, and are often pale and cloudy. Renaut attributes the dissociation of cells to solution of the cement substance, on account of senile involutionary changes, alcoholism, infection, and the associated high temperature. Hektoen says "of the morbid changes of the myocardium proper, none occurs more frequently or under a greater variety of circumstances, than the lesions known as segmentation and fragmentation of the muscle fibres. They are due to a disproportion between the vigor and order of muscular contraction and muscular cohesion."

IV. *Abscess of the Heart.*—This develops in the course of a pyæmia or infective endocarditis. It is a metastatic pyæmic process localized in the heart. Infected emboli are carried into the coronary circulation with a resulting inflammation and suppuration. These abscesses vary much in size, from very small to fairly large.

James Rae Arneill.

HEART DISEASES: NEOPLASMS.

—Primary tumors of the heart are very rare. They may arise in the myocardium, or in the peri- and endocardium, from which points they may invade the heart muscle. They may also take their origin from the valves. They may be single or multiple. They may form nodular circumscribed masses in the heart wall, or project as polypoid growths into the heart cavity. Only rarely do they form diffusely infiltrating growths. Many are of congenital origin. The majority of cases occur in young or middle-aged individuals; a few have been found in old age.

The *myxoma* is the most frequent variety of primary neoplasm of the heart, eighteen cases having been observed. Of these the majority were pure myxomata, the others fibromyxomata. In one case the growth was described as an angiectatic myxoma. As a rule they form polypoid growths projecting into the heart cavities. It is very doubtful, however, if some of the polypoid formations found on the endocardium were really of the nature of neoplasms; rather is it probable that they were masses of newly formed connective tissue of myxomatous type resulting from the organization of thrombi. In a case of fibromyxoma of the left auricle occurring in a girl of four years, Jacobsthal found large numbers of newly developed fibres of yellow elastic tissue. In the majority of cases the myxomatous tumor has been found in the left auricle, very often being attached to the endocardium by a slender pedicle. Papillary myxomata have also been found upon the tricuspid flaps.

Next in order of frequency of the primary cardiac neoplasms is the *rhabdomyoma*. Its peculiar histological structure gives to it a great interest. Cases have been described by von Recklinghausen, Virchow, Hlava, Kolisko, Cesaris-Demel, and Seiffert. The tumor is of congenital origin, and is usually multiple. The nodules are not encapsulated, but are well outlined from the cardiac muscle, and quite sharply demarcated from the pericardium and endocardium. The growths may be as large as walnuts, and are scattered through the ventricular walls and the interventricular septum. On section the nodules are reddish-gray in color. The microscopical appearances are very striking. Trabeculæ of varying thickness showing transverse striations are arranged so as to form small spaces. These spaces do not communicate with each other; they contain large polygonal cells of irregular outline having one or more oval nuclei which are centrally situated. Their photoplasm shows a faint striation. In some cases the cell appears to form part of the wall of the space and sends prolongations across the latter. Both the protoplasm and prolongations of these cells stain like muscle. The spaces and their contents have received very different interpretations from the different observers who have studied this tumor. Hlava regarded them as intracellular, Kolisko as intercellular. According to Seiffert each space and its wall represents a greatly enlarged embryonal heart-muscle cell. The smallest tumor nodules may consist of bundles of delicately striated fibres only, without the peculiar spaces. Of the significance and mode of formation of the cardiac rhabdomyoma we as yet have no satisfactory explanation.

Primary *sarcoma* of the heart is much more rare; and it is very probable that some of the cases diagnosed as such were secondary to some undiscovered focus elsewhere in the body. The reported cases have been in both young and old individuals. The varieties observed were round and spindle-cell forms, myxosarcoma, fibrosarcoma, and angiosarcoma.

Cases of primary *fibroma* of the heart have also been reported, but the true nature of these cases is uncertain. It is quite probable that they represent organized thrombi. Observations have also been made of the primary occurrence of *lymphadenoma*, *cavernous angioma*, and *lipoma* in the heart. The polypoid *cysts* which have been described by a number of writers as primary cardiac neoplasms are without doubt to be regarded as degenerating or partly organized polypoid thrombi. They are found most frequently in the left auricle, are reddish-gray in color, and have a smooth shining surface. On section they show a cystic space filled with the products of the simple softening of the central portion of the thrombus. When organization of the periphery of the thrombus has begun the resemblance to a true cyst is very close.

Primary neoplasms of the valves are more rare than those of the heart wall. A *papillary myxoma* of the posterior tricuspid flap, *multiple myxomata* of the size of peas of the same valve, and *spindle-cell sarcoma* of the pulmonary valves have been reported.

Secondary neoplasms of the heart are also rare but much more frequent than the primary. Secondary *carcinoma* is the most common tumor of this organ. Primary cardiac cancer is of course an impossibility, though in the older literature descriptions of growths regarded as such are found. These cases were either cancer-secondaries, or, as was not infrequently the case, sarcomata were diagnosed as carcinomata. Secondary carcinoma of the heart may arise through metastasis, or by extension through continuity or contiguity through the pericardium from carcinomatous growths in the lungs, œsophagus, or secondary deposits in the mediastinal lymph glands. Metastatic carcinoma of the heart may arise from emboli of cancer cells in the coronary vessels, on the mural endocardium, between the papillary muscles, and on the valves. From a secondary focus thus formed further extension may take place through the cardiac lymph channels. In this manner diffuse carcinomatous infiltration of the entire cardiac wall may take place. In other cases multiple metastases in the heart may be found. These may be found in the walls of both auricles and ventricles. There does not appear to be any favorite seat of deposit. In the majority of cases the carcinoma is of the medullary type. In the event of carcinomata breaking into the vena cava large emboli of carcinomatous tissue may be carried to the right heart where they may become attached to the endocardium or develop as free carcinomatous masses.

Secondary *sarcoma* of the heart, while less common than secondary carcinoma, has been observed by a number of writers. The growths are usually metastatic, but the heart may be involved also by extension through the pericardium from primary mediastinal sarcomata. The tumors may be single or multiple. They may be nodular, diffusely infiltrating, or in the form of flattened plate-like growths more or less sharply outlined. Free sarcomatous masses may be found in the right heart in cases in which the primary tumor has invaded a large vein. In a case described by Osler of sudden death in a child the tricuspid orifice was found blocked by a sarcomatous mass coming from the renal vein. In a case of primary sarcoma of the nose reported by the writer the entire heart wall was found to be infiltrated with sarcoma, while in the right ventricle there was a free sarcomatous mass of the size of a walnut.

Small tumors of the heart may produce no symptoms; larger growths may lead to cardiac hypertrophy, dilatation, valvular stenosis or insufficiency, rupture of the heart wall, secondary embolism, etc. An absolute diagnosis in the majority of cases is impossible. In suspected cases the Roentgen ray might reveal changes of size or form in the heart. If the pericardium is involved and a pericardial exudate present, some of the latter should be withdrawn for examination. The presence of a hemorrhagic exudate would be regarded as favoring the presence of a malignant tumor. Of greater diagnostic significance would be the character of the cells found in the exudate. The presence of numerous mitoses in these, particularly atypical mitotic figures, could be taken as almost positive evidence of the presence of malignancy. The treatment is wholly symptomatic.

Aldred Scott Warthin.

HEART DISEASES: NEUROSES.—THE NERVOUS MECHANISM OF THE HEART.—It has become known to physiologists that the power of pulsation of the heart is not engendered in, or derived from, the nervous system, but rests in the musculature of the organ itself. In the frog and other cold-blooded animals the heart continues for a short time to pulsate with a true rhythm after removal from the body and complete separation from nervous or other connection. The same is true in a minor degree in the higher animals, and while not actually verified by observation, will undoubtedly hold good in the case of man himself. Although striated the cardiac muscular structure is incompletely differentiated, and thus retains the power of spontaneous movement common to all primordial protoplasm. The nervous system, however, exercises a supreme influence over the cardiac movements. Two important sets of nerves derived from the cerebro-spinal and the sympathetic systems are concerned in the regulation and control of the circulatory centre. The scope of this article does not contemplate a complete and detailed description of the nervous supply of the heart and the phenomena of its mechanism. It is sufficient for our purpose to call attention in this place to the major facts relating to the functions of the two kinds of cardiac nerves which have been well established by physiological research.

1. Those derived from the vagus which are chiefly inhibitory or slowing to the action of the heart when subjected to a stimulation of either a direct or a reflex character. The vagus is thus known as the anabolic nerve of the heart. The pneumogastric trunk also conveys the depressor cardiac nerve which enables it to govern and regulate the arterioles in accordance with the demands of the heart.

2. The accelerator, or more properly the augmentor, nerves of the heart, derived chiefly from the first, second, and third cervical ganglia of the sympathetic system. The function of this cord, known also as the *katabolic* nerve of the heart, is to accelerate the frequency of the cardiac contractions and at the same time to augment their force. But when the question is asked, by virtue of what events produced in the heart itself do the impulses of one kind bring about inhibition and those of another augmentation of the impulses, we are met with difficulty. We may speak if we choose of an inhibitory mechanism placed within the cardiac structure, but we have no exact knowledge of the nature of such a mechanism, still less of an augmentor mechanism (Foster). It has been suggested that some of the intracardiac ganglia may serve as a medium for the distribution of these inhibitory or augmentor influences, but the evidence goes to show that the inhibitory impulses produce their effect by acting directly on the muscular fibres themselves. Nor are we in a position at the present time to assign the proper function of these ganglia, although it is believed that their influence is chiefly of a trophic or nutritional character. But, while the nervous system neither initiates nor controls the rhythmic movements of the heart, this function at once goes astray if removed from nervous governance. It is by the nervous system that the heart-beats and the calibre of the small arteries are brought into relation with each other and with almost every part of the body. It is by the nervous system acting either on the heart or on the small arteries that a change of circumstances affecting either the whole or a part of the body is met by compensatory or regulating changes in the flow of blood; that an organ has a more full supply of blood when at work than when at rest; that the tide of blood through the skin rises and ebbs with the rise and fall of the temperature of the air; that the work of the heart is tempered to meet the strain of overfed arteries, and that the arterial gates open and shut as the force of the central pump waxes and wanes. We have thus learned the seat of the automatic and rhythmic action of the heart, and are able to descry the part played by the nervous system in controlling the force, frequency, and rhythm of the muscular movements, and the tonicity or laxity of the vascular walls. But this knowledge does not aid us greatly in a definite appreciation of the pathogeny of the various disordered states of the organ which we designate as neuroses, nor does it quicken to any great extent our perception of the clinical phenomena, or our knowledge as to the therapeutic management of these conditions. The physiological relations existing between the vagus and sympathetic supplying cords on the one hand and the intracardiac ganglia and muscular structure on the other have not been sufficiently defined to enable us to agree upon any fixed or definite anatomical, pathological, or even clinical basis in our attempts to explain the cardiac neuroses.

NOMENCLATURE OF THE CARDIAC NEUROSES.—Until a very recent period the term palpitation was made to cover practically all of the nervous disturbances of the heart. With increased experience and additions to our clinical knowledge this restrictive appellation no longer serves its former purpose. It would appear indeed that we are in danger of going too far in the other direction. During the last decade or two there has developed a tendency to an embarrassing multiplication of terms in labelling the functional derangements of the heart. Furthermore, no two writers appear to agree exactly in classifying these disorders. It thus transpires that the nomenclature of the subject is at the present time in a most bewildering, it might almost be said chaotic, state. This is perhaps to some extent inevitable. Some of the conditions which we find it convenient to describe under distinctive titles so shade into each other that it is difficult to decide where one begins and another ends. For example, the condition described as palpitation may present at times the symptoms of neurasthenia cordis, or of arhythmia; while in tachycardia, the features of palpitation, or even of pseudo-angina, may obtrude themselves. Some of the terms employed do not constitute true symptom groups—they are mere symptoms themselves and not distinct diseases.

After much anxious thought and study of this subject, it has seemed to the author proper to present an account of these nervous manifestations, each under the head of the most prominent clinical features exhibited, noting the points of contact with other neurotic manifestations and such additional facts as our present state of knowledge would appear to warrant. It must be said that no perfectly satisfactory clinical classification of these disorders is possible until further light has been shed upon the physiological inter-relations existing between the supplying nerves, the cardiac ganglia, and the muscular structure of the organ itself. It has seemed to the writer, however, that all we know at the present time concerning the clinical and pathological features of the cardiac neuroses may be properly included under the following heads: (1) Palpitation; (2) tachycardia; (3) bradycardia; (4) the dyspeptic heart; (5) neurasthenia cordis; (6) the irritable heart; (7) arhythmia, including delirium cordis and tremor cordis; (8) the heart in Graves' disease; (9) angina pectoris and pseudo-angina. Of these terms it may be said that palpitation, tachycardia, neurasthenia, arhythmia, and angina are necessary and essential; the remainder might properly be omitted, but they are found in contemporaneous literature and may for the present be used provisionally as marking points of which we have no exact scientific conception.

PALPITATION.—According to Balfour all who suffer, or think they suffer, from disease of the heart are prone to palpitation. Under Laënnec's definition, any person whose heart's action obtruded itself upon the consciousness might be said to have cardiac palpitation. In accordance with the modern terminology, however, the name is used to cover a much more limited class of cases. One by one symptoms formerly referred to as falling under this term have been relegated to other forms of disorder, until at the present time palpitation has become quite unfashionable. Several writers mention it only as a symptom of other neuroses. In the author's opinion, however, it may still be regarded as a substantive affection covering a distinct symptom group.

Symptoms.—Probably some palpitation of the heart falls within the experience of every one. Being very near to our consciousness, eccentricities of the heart are usually attended by great perturbation of the nervous system. The attacks usually come on suddenly, independently of any mental or physical effort, and vary in severity from a mere sense of discomfort or uneasiness to a high degree of pain and distress. Some persons experience darting pains through the heart during the attacks, especially on attempting to take a deep inspiration. It is often brought on by a full meal and the belching of gas gives relief. The heart appears, as variously described by the patient, to jump, to roll, to throb, or to stand still. On physical examination the apex beat will probably be found to be increased in frequency and possibly in force during the attacks. It strikes the palpating hand with a quick throb which extends to the greater arteries. No murmur is present except in anæmic cases. Nor are there other signs of disturbance or lesion except possibly a slight intermittence or irregularity at times. The attacks may last for from a few moments to several hours, or at intervals for days together. One paroxysm generally implies a susceptibility to others.

Etiology.—The causes of this disorder are legion. Any sudden emotion—surprise, grief, fear, joy, or disappointment—may cause a transient palpitation in nervous persons. More severe and persistent forms are usually the result of some error or indiscretion on the part of the patient. Inordinate use of tobacco, tea, or coffee, dietary indiscretions, excessive venery, self-abuse, and late hours are fruitful causes. The condition is far more common among females than in males, and is especially frequent in the anæmic conditions of young girls. More or less palpitation is a common accompaniment of organic disease of the heart, brain, and spinal cord.

Like other pure neuroses, simple cardiac palpitation gives rise to no morbid structural changes which are tangible to our senses.

Prognosis.—The disorder is as a rule readily amenable to treatment, a withdrawal of the cause being usually sufficient to cause a speedy disappearance of the symptoms. At times, however, it is exceedingly obstinate and taxes the resources of the practitioner to the utmost. It may extend over years of time, but never *per se* endangers life.

Treatment.—This consists first in the removal of the cause, if it can be ascertained. It is quite useless to administer drugs with a view to relief of this disorder to a person consuming habitually excessive quantities of tea or tobacco. A careful mode of life is an important desideratum. Prudent and regular habits of eating and sleeping and moderate outdoor exercise are points to emphasize. A morning shower bath of moderately cold water followed by a vigorous friction of the skin with a coarse towel is a useful measure in lessening the liability to the attacks. In habitual cases the daily administration of three five-drop doses of the tincture of digitalis, combined with ten-grain doses of bromide of potassium, or sodium, has a valuable effect in warding off the paroxysms. It is important to give the patient full assurance that he is in no danger whatever as to his life. During the paroxysm the administration of some of the diffusible stimulants or antispasmodics to excite vagus inhibition is indicated. The old-fashioned combination of valerian, Hoffman's anodyne, and lavender is very serviceable. A good formula is as follows: ℞ Spiritus ætheris compos., Tinct. valerian., āā ʒ vi.; Spiritus lavandulæ compos., ʒ iv. M. et Sig.: ʒ ss. every half-hour until relief is obtained. The writer has found the application of some form of cutaneous irritant, in the shape of a small section of mustard leaf or thapsia plaster, to some section of the body remote from the heart so as to attract the patient's attention elsewhere, to serve a useful purpose. The administration of small quantities of brandy or ammonia may be useful in some cases, but it is seldom that morphine is required in simple palpitation. The application of a sinapism or a belladonna plaster to the heart is sometimes useful. It is said that certain mechanical means, such as holding the breath after a deep inspiration, pressure on the abdomen, etc., will sometimes abort an attack, but the author has discarded these measures after repeated futile trials. Compression of the vagus and sympathetic nerves in the neck and the use of faradism are worthy of a trial in obstinate cases.

Tachycardia.—Etymologically (*ταχύς*, quick, *καρδία*, heart) this word means a quick heart, but the name does not afford altogether an accurate conception of the disease. Tachycardia is characterized by an increased frequency of the cardiac pulsations, but not every person with a quick heart can be said to be a victim of the diseased condition which we now recognize under this appelation. Although the term has been subjected to great abuse, tachycardia properly embraces a fairly constant symptom group, and as such is entitled to be regarded as a separate and distinct morbid entity, and not a mere symptom. Many persons have normally a heart's action of 100 or more, but this does not constitute tachycardia, nor does the rapidly acting heart of emotional disturbance, or that associated with tuberculosis, fevers, organic disease, or Graves' disease. Many theories have been proposed in explanation of this strange affection, but none of them is fully satisfactory. In the present state of our knowledge we can do little more than guess whether the immediate causes lie in the augmentors of the heart, the vagus, the ganglia, or the musculature, or whether it be of centric origin. Possibly it is due at times to some eccentric irritation, such, for example, as a diseased ovary, a floating kidney, or a neuritis of distant cords. It seems rational to attribute the trouble in most cases to overstimulation of the accelerators or paralysis of the inhibitory nerves; probably in extreme cases both factors are operative.

Morbid Anatomy.—This condition is essentially a neurosis. It follows therefore that in the few autopsies which have been made in the case of persons who suffered from tachycardia during life no constant primary changes have been found, although there have been as a rule some marks of cardiac decadence in the shape of secondary degeneration of the muscular structure. Examinations of the vagus, the sympathetic, and the intracardiac ganglia have been negative.

Causation.—The etiology of tachycardia is in many cases past finding out. It is most likely to occur in persons of a neurotic or hysterical temperament, and in some cases it appears to be hereditary. Possibly such factors as worry, overexertion, frequent excitement of the emotions, and the abuse of alcohol and tobacco are concerned in the causation. Dyspepsia and diseases of the uterus and ovaries form a basis for many cases. Probably onanism and sexual excess or repression have some bearing on the causation. In a recent case, under the writer's observation, of convalescence from typhoid fever the pulse would quickly rise from 80 to 150 without apparent cause. The disease occurs with about equal frequency in the two sexes. It is rare under twenty, but no age is exempt. Perhaps a majority of cases are seen in persons in middle life.

Symptomatology.—The following clinical features are fairly uniform. The patient may have felt in an average state of health for a variable period, when a peculiar sensation of lassitude or restlessness steals over him. His apprehensions may be aroused and slight vertigo experienced. Perhaps the extremities become cold and numb, and a shivering feeling creeps up and down the spine. The face may become ashy or mottled. A sensation of oppression or tightness, but not of palpitation, is felt about the heart. This may occasionally amount to actual pain. During a marked attack the patient is quite helpless. He can neither stand, nor sit, nor lie with comfort. He is irritable and generally miserable. An examination of the heart will now show a pulse rate of 120 to 140 or 160. Sometimes it is so frequent as to be counted only with the use of the sphygmograph. A case was reported by Dr. Bristowe of 308 per minute! The use of the stethoscope shows no murmur or other evidence of organic disease of the heart. The pulsations have a tick-tack sound and not all of them are propagated as far as the radial artery. In most cases the urine is scanty, but nervous polyuria may exist. The attacks may last for a period ranging from a few minutes to several hours or even days. In a case reported by Bouveret the patient suffered for thirteen days (Allbutt). Permanent tachycardia is an expression of organic disease, usually in the course of the vagus or medulla, or an evidence of pontine softening with paralysis. The paroxysm generally ends suddenly with a few parting twinges of pain or twitching. During some attacks, especially in long-standing cases, signs of cardiac dilatation with œdema of the lungs, swelling of the ankles, and albuminuria may supervene. Death may possibly occur from asystole or syncope, probably nearly always from the latter. During the intervals patients recover their ordinary health but the substratum remains.

Prognosis.—This has to some extent been foreshadowed in the preceding paragraph. The ultimate termination in individual cases is always doubtful, but the immediate prospect, especially during the early years, is hopeful. Patients sometimes tolerate the affection for many years, dying eventually of old age.

Treatment.—We cannot with certainty arrest a paroxysm of tachycardia when it is under way, but we can lessen the tendency to recurrence by prudent and regular habits of life, by the avoidance of excess in every direction, and by the cautious administration of such tonics as strychnine and arsenic combined with a little digitalis or caffeine. During the attacks the exhibition of two or three half-ounce doses of brandy combined with five or ten drops of tincture of digitalis may be found useful in mitigating their severity. Strong coffee internally and the application of the ice-bag to the præcordium may have the effect of inhibiting the vagus, as may also electrization of the vagus, placing the positive pole over the inner border of the sterno-mastoid muscle and the negative up and down the lower part of the sternum. According to Whittaker, morphine is of little value in pure vagus tachycardia. Nitrite of amyl and nitroglycerin are likewise useless. Compression of the chest has been recommended by several well-known observers. The patient lying on his back thrusts his feet as hard as possible against the foot of the bed, then pressing his arm closely to his sides he takes a long inspiration. Now closing the glottis he makes a strong expiratory effort, thrusting hard at the same time against the walls of the chest with the upper arms and clasping them with the forearms. By this means it is stated that the rate of the heart may be controlled and the organ even caused to intermit in its action. A morning shower bath and the graduated douche or cold pack has been employed with advantage. When tachycardia is due to recent strains of the myocardium, the best treatment seems to be absolute rest, the full action of belladonna or atropine as indicated by slight dilatation of the pupil, being maintained at the same time.

Bradycardia—(from βραδύς, slow, and καρδία, heart), otherwise known as araiocardia, oligocardia, pulsus rarus, pulsus tardus, etc. This condition cannot in our present state of knowledge be identified as a distinct affection. The name connotes nothing and signifies nothing more than a phenomenon common to many definite groups. There is not, as in tachycardia, a particular symptom group of which bradycardia itself is the centre. Several cases of what was supposed to be essential paroxysmal bradycardia have been reported, but a closer and more continued observation has shown that these cases were always secondary. A description of the condition therefore can consist only in detailing the various diseases or disorders of which it is one of the clinical features. The phenomenon is no doubt partly due to direct or reflex irritation of the vagus centre, or the vagus trunk, and partly to increase of arterial pressure by vasomotor or purely muscular contraction of the peripheral arteries. It may also be brought about by diminution of pressure due to loss of blood, to direct influence on the heart muscle of substances circulating in the blood, and finally to anatomical changes occurring in the musculature of the heart or of the endocardium. Some persons have naturally a slowly acting heart, without apparent detriment to their vital functions. The well-known case of the first Napoleon is a familiar example. According to his physician, Corvisart, the apex beat of this by no means slow individual averaged only 40 per minute. While bradycardia is undoubtedly produced through some form of defective innervation, it cannot be accurately defined as a neurosis. It is an incident of organic disease of the brain and its meninges and of the spinal cord. During the progress of a case of pachymeningitis in a little boy, aged five years, lately under the writer's care, the heart beats fell as low as 48 per minute for several days before death. It may occur as a result of fracture of the vertebræ with compression of the cord, usually in the region of the fifth or sixth cervical vertebra. It occurs in epilepsy and is an incident of many infections, including typhoid fever, pneumonia, erysipelas, and rheumatism. Slow heart is often observed in puerperal women, and it may result from the presence of bile in the blood, of anæmia, of diabetes, or it may be due to many of the disorders of the intestinal tract. It is probably not often caused by alcohol or tobacco, nor is it an incident of organic disease of the heart, except when the myocardium is involved. It is occasionally seen in aortic stenosis and may result from occlusion of the coronary arteries.

The condition calls for no special form of treatment, its management being involved in the general treatment of the associated disease or disorder. It is usually advisable, however, to administer digitalis in moderate doses so as to maintain the metabolism of the myocardium and enable it to withstand the great strain produced by the conditions under which the circulation is carried on.

The Dyspeptic Heart.—Here we have another name applied to certain neurotic states of the heart. The term has not acquired extensive vogue as yet, but its use appears to be increasing. Is there a symptom group referable to the heart as its centre occurring with sufficient frequency or uniformity to warrant the addition of the term dyspeptic heart to our nomenclature as a separate and distinct affection? After much careful thought and observation the writer is led to answer this question in the negative. Aberrations of the digestive functions lead to all kinds of disturbances of the heart's action, whether it take the form of palpitation or of tachycardia, of neurasthænia cordis or of pseudo-angina; but they present nothing peculiar or distinctive. The neurotic cardiac manifestations due to digestive trouble are quite similar to those resulting from other causes, plus the presence of clinical features referable to the stomach or intestines. The association of gastric and cardiac trouble is one of extreme frequency, so much so that it is important to investigate every case of functional cardiac disorder for a possible digestive origin. These disturbances are of two kinds: first, reflex, giving rise usually to simple nervous palpitation, but not infrequently to tachycardia, to bradycardia, and even to pseudo-angina. It is probable that almost every case of so-called *tremor cordis* is of gastric origin. Second, the most severe and even dangerous symptoms of mechanical disturbance of the heart arise from the presence of an overloaded or tympanitic stomach. Some of these cases closely resemble in their manifestations organic disease of the heart itself, and it is not to be doubted that not a few sudden deaths attributed to heart disease might more justly have been credited to an abused and rebellious stomach. These cases of mechanical interference with the action of the heart are not, however, strictly speaking, neuroses, and do not properly fall within the domain of our present subject. It need only be added that in all cases of cardiac trouble of gastric origin therapeutic measures are to be addressed to the stomach and not to the heart.

Neurasthenia Cordis; The Weak Heart.—This condition is very similar in its manifestations to the irritable heart of some authors. It is practically identical with the not infrequent class of cases somewhat loosely denominated weak heart. The condition denotes aberration or insufficiency of the heart, the result of defects of innervation. It is clearly a neurosis, and in our present state of knowledge excludes all organic disease, although the time is probably close by when keen observers will be able to distinguish pathological departures in the intimate structure of the cardiac ganglia or nerve trunks, or perhaps in the muscular substance of the myocardium. Patients suffering from this affection usually belong to the neuropathic type, which may or may not be the result of defective endowment, hereditary or otherwise. It is brought on by overstudy, by sexual excess, or possibly by coitus reservatus, by long continued depressing emotions, failure in business, frequent excitements, long marches, and exhausting efforts of all kinds. Onanism and unrequited love have been cited as fruitful causes. It is frequently seen after recovery from long attacks of prostrating diseases, more especially the essential fevers. Being to some extent an occupation neurosis, it is far more frequent in males than in females. It seems to occur with unusual frequency among ironworkers engaged in high-building operations.

Symptoms.—By what means are we able to identify the condition of neurasthenia cordis? The cardiac features predominate, although general nervous manifestations are usually prominent. The patient as a rule is fretful, irritable, and fidgety. He is easily startled on sudden excitement and is apt to be more or less hypochondriacal in his tendencies. The cardiac attack itself is liable to begin with some quickening, possibly more or less irregularity or intermittence of the heart. The first cardiac sound is short and lacking in volume; the second sound is not accentuated. Palpitation is not common, but there may be a feeling of more or less uneasiness about the heart. The patient is apt to show vasomotor disturbances in the shape of frequent changes of color in the face and sudden coldness, followed by burning heat of the hands and feet. There are no œdema of the feet or ankles and no dyspnœa, but in severe cases there may be sufficient local distress to resemble pseudo-angina. The sleep is liable to be restless and the patient wakes with a sudden jump of the heart. After the stage of irritability the patient falls into a state of more or less depression, marked by defective nutrition. Insomnia is a constant symptom. In some cases the patients are unable to be up and must remain in bed. The pulse continues to be weak and excitable and the sphygmograph shows marked dicrotism.

Diagnosis.—The diagnosis of neurasthenia cordis is to be reached by discriminating consideration of the symptoms, as above outlined, and by exclusion. The term weak heart is too often used as a cloak. This condition is not one of palpitation on the one hand, nor of tachycardia on the other. The patient's general long-continued neurasthenic state, coupled with the cardiac symptoms and with the absence of any signs or symptoms of organic trouble, of Addison's disease, diabetes, carcinoma, or tuberculosis, renders the existence of neurasthenia cordis a practical certainty.

Prognosis.—Neurasthenia cordis seldom destroys life directly, but it forms a bad accompaniment for acute prostrating diseases. Patients succumb much more readily to typhoid or other intercurrent affections. The condition is essentially chronic and a long duration may usually be predicted.

Treatment.—This should consist chiefly of cheerful surroundings, agreeable society, and pleasant occupation. The food should be simple, abundant, and easily digested. Daily systematic outdoor exercise, particularly walking at a slow or moderate pace, should be advised. A morning shower bath as cold as the patient can endure and react from with comfort is a useful habit to inculcate. Da Costa allows alcohol in liberal quantities to patients of this type, but it seems to the writer that this remedy should be used as discriminatingly in these cases as elsewhere. One of the lighter wines may be allowed with meals, but in most cases the extract of malt will answer all purposes to be gained from alcohol and with less likelihood of unpleasant results. A very useful stomachic tonic and reconstructive is as follows: ℞ Acid. hydrochlor. dil., Tr. nucis vomicæ āā fl. ʒ iv.; Elixir lactopeptin q.s. ad fl. ℥ iij. M. et Sig.: A teaspoonful in half a wineglassful of water before each meal. Cascara, rhubarb, and Kutnow's improved sprudel salt used alternately are to be preferred for the constipation of these sufferers. The bromides, valerian, and even opium may be required at times. Digitalis and nitroglcyerin are useless.

The Irritable Heart.—Under this name a form of cardiac neurosis is described in various ways by different writers. The term was originally used by Da Costa in describing a peculiar cardiac excitability which he found to exist among soldiers in the field. The condition is much more frequent among men than among the gentler sex, and is usually seen prior to the thirtieth year of life. The patient complains that he is never free from a tired feeling about his heart, sometimes a sharp pain is felt. The organ is liable to throb and jump and is never entirely outside of consciousness. Even when the patient is lying quietly in bed it makes itself a nuisance, banging away at the time when he should be asleep, while exercise or exertion brings on a violent beating (Allbutt). In most cases there is a history of overexertion. The trouble frequently remains among college men as a reminder of the rush and crush and indiscretions and untamed passions of youth. Spasmodic bouts of study, overdoses of alcohol and tobacco, late suppers, overwork in the gymnasium, and other incidents of an irrational and irregular life in a nervous or dyspeptic young person usually go to form the groundwork of the irritable heart. A physical examination may show a slight degree of hypertrophy, but dilatation is most frequently present. The peripheral arteries are lax and the pulse is dicrotic; its slackness is in marked contrast with the excitable state of the heart itself. The rhythm of the cardiac contractions is often a little uneven and the second sound at the apex too loud. The action of the heart may seem labored and heavy under the palpating hand. A murmur may possibly be heard, but more often simply an impurity of the first sound, as though it were dimmed by a distant murmur.

Treatment.—Prevention of this trouble during the early years of young adult life is of the utmost importance. Young men especially should be warned of the dangers of an unsteady method of life. Violent and irregular exercise, drinking and smoking to excess, late hours and sexual indiscretions should be guarded against. Adolescent youths are prone to err in all of these directions, and it is the function of older and wiser persons to inculcate correct and uniform habits. If the condition which we know as the irritable heart has actually become established, the medical adviser of the patient must set himself to the task of repairing the mischief without delay. The patient's daily habits must be carefully investigated, and his life made as tranquil and as free from sources of irritation or excitement as possible. His good health cannot possibly be recovered by any other means. It is useless to give digitalis or other cardiac tonics or stimulants, though at times a systematic exhibition of bromides in small doses may serve a useful purpose. In many cases a complete change of scenery and surroundings is required. A temporary removal to a quiet rural locality absolutely free from temptations to indiscretions or excess is usually followed by good results.

Arrhythmia (*a*, privative, and ρυθμός, rhythm), known also as the pulsus inæqualis or pulsus irregularis, is a disturbance of the rhythmic contractions or regularity of the heart. The rhythm of the heart may be normally intermittent or irregular in some persons, and slight deviations of this kind are not incompatible with the complete and proper performance of the cardiac functions. It is not uncommon to notice certain disturbances of the rhythm in childhood, especially during sleep, which disappear after the child wakes and runs about. This has no pathological significance, but the irregularities which are increased by exercise or excitement, especially if accompanied by pain or palpitation, are always a sign of gravity. Irregularities of the heart may be due to direct, reflex, or toxic causes, or a combination of any or all of these. According to Roy and Adami, they are brought about by the failure of the auricles to respond to some of the contractile influences which reach them from the sinus (venosus), or by the interference of the sinus and ventricular rhythm with each other. Ultimately the cause of all irregularity may be traced back to inhibition of the heart through, but not by the vagus. Simple intermittence is always an indication of cardiac failure due to anæmia, overwork, or worry. It may be associated with valvular lesions, but has only an incidental connection with them. Intermittence may be true or false. In true intermittence the heart itself actually omits a contraction, while in false intermittence the organ contracts but the pulse wave is not transmitted to the wrist. These insufficient waves are known as "frustrate" contractions and sometimes observe a form of regularity themselves, *e.g.*, the second, third, or even up to the tenth or fifteenth contraction may be a frustrate, or two frustrates may appear together successively, or they may be irregular for some time and then show themselves in rapid succession. In some instances these frustrate contractions are simply due to a slight nervous disturbance and have no real significance. Among the writer's patients is a man of sixty, usually in the best of health, whose heart has shown these intermissions for the last fifteen years. Sometimes strong and weak beats alternate with each other regularly, giving rise to what is termed the *pulsus alternans.* Two strokes in quick succession followed by a longer pause constitute the *pulsus bigeminus*, three strokes the *pulsus trigeminus.* A combination may occur constituting the *pulsus bigeminus alternans.*

ALLORRHYTHMIA (ἄλλος, another) is a condition in which a distinct method is observed, the irregularity being always the same. When, in addition to this state, the heart is tumultuous, it is known as *delirium cordis.* The writer has at the present time a case under observation in which acceleration, intermittence, and irregularity are combined, the pulse rate never being less than 160 per minute, and complete allorrhythmia being present. The *pulsus paradoxus* is more a disturbance of the pulse than of the heart, the pulse being weaker instead of stronger during inspiration. The rhythm of the heart may be in no wise disturbed, but its contractions are not strong enough to propel the blood through the vessels of the thorax against the inspiratory suction force which arrests or holds back the blood wave.

Causes.—Arhythmia is found occasionally in all of the other cardiac neuroses and the causes which originate those conditions likewise bring about irregularity of the cardiac rhythm. Disease of the brain and spinal cord and pressure upon the nerve trunks by tumors or inflammatory products are among the direct causes. In leucocythæmia and progressive pernicious anæmia, conditions interfering with the nutrition of the heart, arhythmia is a frequent accompaniment. It is sometimes due to the pressure on the heart of a large pleuritic or pericardial effusion, or a flatulent or distended stomach. Among the reflex causes may be included diseases or disorders of distant organs or parts, viz., an inflamed ovary or uterus, the passage of a gall-stone, a blow on the stomach, a sharp attack of intestinal colic, or an operation on the pelvic or abdominal viscera. The toxic causes embrace certain drugs, notably muscarin, alcohol, digitalis, strophanthus, tobacco, chloral hydrate, and aconite, all of which may cause interference with the cardiac rhythm. Certain infections, like those of typhoid fever, scarlatina, diphtheria, etc., produce this result. In a severe case of scarlatina under the writer's care in a little girl aged six years, the heart remained intermittent during sleep for some weeks after the passage of the fever.

Symptoms.—The symptoms of arhythmia are referable chiefly to the heart and pulse and are of an objective character. Many persons have an irregular or an intermittent heart for years without becoming aware of it. In many cases there are no subjective symptoms whatever, while in others there may be a feeling of anxiety about the præcordium or even severe palpitation or anginal symptoms. In grave cases there may be signs of pulmonary œdema, cyanosis, or dropsy. The condition is to be recognized only by a careful observation or actual count of the heart's pulsations.

Prognosis.—This depends entirely upon the cause. It may possess no evil significance whatever, or it may be a harbinger of approaching dissolution. As a rule arhythmia may be looked upon as a graver symptom than palpitation. If it disappears under excitement or exercise, it may be disregarded as of little consequence, but if increased under these circumstances it is a sign of gravity. The intermittence or irregularity resulting from the abuse of alcohol, tobacco, and bad habits at the table generally disappears on removal of the offending cause.

Treatment.—The systematic treatment of arhythmia is closely involved in that of the associated conditions, although the symptoms of irregularity and intermittence will at times require direct attention. If there be present a flatulent or an irritable stomach, measures directed to its relief should not be delayed. If the uterus is displaced, it should be restored to its proper position; if an ovary is diseased or a kidney loose from its anchorage attention must be given to these matters. The arhythmia following acute febrile states generally disappears with the lapse of a few weeks more or less. In most cases of persistent arhythmia the daily administration of strychnine, in doses of not less than one-thirtieth of a grain before each meal, is indicated; with this may be combined one-half to one grain of digitalis or caffeine, or two or three minims of the tincture of strophanthus. In cases of high arterial tension, as shown by a hard, incompressible pulse, the use of nitroglycerin is required. If the action of the heart be heaving and tumultuous a warm bath (96° to 100° F.) may be of service, provided there is no atheroma or other organic trouble with the heart or arteries. Mild cases are often benefited by the systematic use of cold baths. Icebags to the præcordial region have been recommended by some excellent authorities. The use of massage is frequently productive of good results. Moderate exercise, regular habits, and proper food should be insisted upon.

TREMOR CORDIS.—This term savors somewhat of pedantry. It should never be understood as being applicable to a morbid entity, but to a symptom sometimes met with in neurotic persons, especially those of a dyspeptic tendency. It is a peculiar form of irregularity of the heart which seizes the sufferer without a moment's warning. The symptom is exceedingly alarming to the patient but is devoid of danger. "Like a bolt from the blue, and with as little warning, a quiet, steady heart is suddenly seized with a rapid fluttering and the ordinary full pulse of health suddenly drops to a mere tremulous thread" (Balfour). The attacks may vary in duration from three or four to a series of short, rapid, incomplete systoles extending over several seconds. On laying the hand over the heart a delicate, tremulous sensation is felt and the radial pulse is scarcely perceptible. The paroxysm ends suddenly with an unusually forcible beat and is never attended by faintness or vertigo. There is no doubt some weakness of the myocardium and cardiac tonics are required, but all direct medication must be subordinated to careful dieting and promoting the general health.

DELIRIUM CORDIS denotes an extreme degree of irregularity accompanied by intermittence and a rolling or staggering sensation conveyed to the palpating hand. It is usually classified as a neurosis, although, as it seems to the writer, improperly so, as true examples of the condition are found only in cases of dilatation and, very rarely, in mitral stenosis. Delirium cordis is not very amenable to treatment, but large and frequently repeated doses of digitalis sometimes give temporary relief.

THE HEART IN GRAVES' DISEASE.—Graves' or Basedow's disease, more recently known as the thyroid cachexia, is classified by numerous authors among the cardiac neuroses. This, it seems to the writer, is not fully warranted. The clinical triad which constitutes the basis of a typical case of Graves' disease are, first, a rapidly acting heart; second, enlargement of the thyroid gland; and, third, protuberance of the eyeballs. All of these symptoms are not invariably present. It often happens that the bulging eyes, or hypertrophied thyroid, are not in evidence. The rapid heart is the most constant symptom, but the writer has seen more than one case presenting all the active signs and symptoms of

Graves' disease, with a heart's action little or not at all accelerated. In a well-marked case of thyroid cachexia, however, the action of the heart is very rapid, amounting to 120 or more beats to the minute. This is often accompanied by a violent throbbing, which extends even to the small arteries. The sounds of the heart are also greatly augmented in volume, being audible in some instances at a distance of several inches from the chest. This peculiar action of the heart differs from simple palpitation by its continuity and by its embracing the small arteries as well as the heart itself in the throbbing. At first there is no structural change in the heart, but the rapid and perturbed action is associated with a falling-off in the ventricular output, and this ultimately leads to residual dilatation with its attendant train of evils. The treatment of the thyroid cachexia is to be directed to the general condition and not to the heart, although a little digitalis combined with Hoffman's anodyne or valerian may be exhibited to mitigate severe throbbing. General tonics, outdoor air, and good food, supplemented by the use of the thyroid or thymus extract, are recognized at the present time as offering the best hope for a modification of the course of this prolonged and obstinate affection.

Angina Pectoris.—This name was introduced by Heberden in 1768. It was intended to denote a strangulation (*angere*, to bind, to strangle). The affection has been known as stenocardia, sternalgia, and breast-pang. There are two varieties, the true, or angina pectoris proper, and the false, or pseudo-angina. True angina is always attended by structural changes and is no more a neurosis than is atheroma or endocarditis. It is usually treated as a neurosis, however, and this is at least partially justified by the fact that the most formidable and striking manifestation of the trouble undoubtedly has its origin in some of the nerve structures communicating with, or located within, the heart. Many authorities have regarded it as a neuralgia. Pseudo-angina is not attended by organic change and is unequivocally a neurosis. The features of false angina are not usually so severe as those of angina vera, but it is not always possible to separate the two. A fatal issue has undoubtedly resulted from pseudo-angina pectoris in some instances.

Causation.—The structural changes which constitute the basis of true angina pectoris do not occur in early life. Thus the affection seldom makes its appearance before the fortieth year of age. All influences which give rise to sclerosis or atheroma of the arterial coats tend to lay the foundation of this dreadful disease. These are notably alcoholic excess, high living, syphilis, gout, lead-poisoning, and overwork, especially of a mental or sedentary character. Probably ninety per cent. of cases occur in males. It is especially prone to appear in persons in the upper walks of life, those of an intellectual occupation being most liable to it. Physicians, clergymen, lawyers, and writers supply the greater number of victims. Heredity plays a rôle in some instances. The paroxysms may be precipitated by exhaustive work or sudden excitement, anger, fright, etc. A patient under the writer's observation suffering from a double aortic lesion developed attacks of unmistakable angina on two successive occasions when taken before a class of students.

Morbid Changes in True Angina Pectoris.—Atheroma of the coronary arteries is the most constant lesion present. Welch found this change in every one of six fatal cases. Embolism of these vessels may also be present, as pointed out by Cohnheim and Virchow many years ago. The process is apt to begin in the ascending aorta at the point of origin of the left coronary artery. The calibre of this vessel may become entirely occluded, or so contracted that a bristle cannot be passed into it. Various other organic lesions have been observed, notably fatty degeneration of the heart, calcification of the aortic valves, aneurism of the aortic arch, pericarditis, and endocarditis. Not every case of coronary sclerosis is accompanied by angina pectoris. The lumina of the vessels are sometimes left sufficiently patent to admit of enough blood, and in other cases the cardiac circulation is carried on by supplemental coronaries which remain unaffected. It will thus be seen that an imperfect metabolism of the myocardium furnishes the groundwork for angina pectoris. No one has ever seen the heart during a paroxysm of angina, but reasoning from analogy it seems probable that the seizures are precipitated by a sudden ischæmia of the cardiac muscles, the blood supply of the coronaries being for the moment totally, or almost totally, arrested. Pseudo-angina may be produced by any of the causes which have been enumerated as producing other cardiac neuroses. It is in greater or less degree an occasional concomitant of those affections. Probably "angina dyspeptica," a mere gaseous dilatation of the stomach, constitutes a majority of the cases of pseudo-angina pectoris in nervous subjects.

Symptoms.—The paroxysm may set in suddenly without previous warning, although the marks of arterio-sclerosis and general failure of the health and strength may have shown themselves for some years. Cardiac palpitation, arhythmia, etc., may also have been experienced. The attack may come on when the patient is sitting quietly in bed, but is most likely to appear during some exertion, such as climbing a hill, breasting the wind, or straining at stool, or when laboring under some form of excitement. In true angina the seizure is of overwhelming suddenness and of unspeakable intensity. The pain begins in the præcordial region, usually about the midsternum, and radiates as a rule upward into the left shoulder and down the left arm, perhaps as far as the finger ends. Sometimes it is propagated in the direction of the right shoulder, or possibly downward toward the leg or the lumbar region. The nervous system is acutely alert. One of the most characteristic features is the feeling of imminent death. Some patients state that the heart feels as though it were being tightly squeezed in the grasp of a gigantic hand. Probably no condition in the entire range of our knowledge entails more dreadful agony than that of a typical attack of true angina. In some cases a sense of coldness, numbness, deadness, creeping, or other vaso-motor disturbance is felt. In others the pain may not be so acute, but takes the form of a dull ache (angina sine dolore) and is overshadowed by the intense anxiety. During the attacks of angina the features are haggard and the face is blanched; the forehead is bedewed with a cold sweat. The respiration, as a rule, is in nowise affected but may be hurried and superficial. The patient is well able to take a deep breath, but is afraid to attempt it. He usually prefers to keep perfectly quiet in a sitting or upright posture for fear of increasing the severity of the paroxysm. A physical examination may or may not show the signs of organic heart disease; the most frequent lesion is aortic stenosis. During the attack the heart's action may be increased or diminished in frequency. In one of the writer's patients it sank below 40 per minute. The blood pressure is always raised at the beginning of the attack. The seizures may last for from a few moments to an hour or more, probably five or ten minutes being about the average. After the attack, which may cease as suddenly as it set in, the patient feels weak and exhausted for a short time. A sensation of numbness and formication in the arms may be experienced. There may be a considerable belching of gas and voiding of a large quantity of urine.

Diagnosis.—This is usually not difficult. No other condition presents the same complex of symptoms—sudden irradiating pain, squeezing, tightening, constriction, overwhelming sense of impending death, etc. As distinguishing between true and false angina, Huchard's aphorisms, while not infallible, are very important: (1) Every angina produced by effort is a true angina. (2) Every angina which occurs spontaneously, without effort, is a false angina. (3) But an angina occurring at night, though independent of effort, is a true angina. Disturbance of the special senses, hysterical manifestations, etc., are far more characteristic of false than of true angina. The absence or presence of signs of organic heart disease is important in the diagnosis. The hysterical pseudo-angina of young women is excluded by the sex and age of the patient, the ability to scream and throw herself about, and the probable presence of anæmia or menstrual disorders. The pseudo-angina of alcohol and tobacco occurs as a rule in young persons and can generally be recognized by the history of the case. The pain here is of subordinate severity. In cardiac asthma dyspnœa is a marked symptom, but is entirely absent in angina pectoris. Then in cardiac asthma are superadded the symptoms of blood stasis in the extremities, cold hands and feet, hyperæmia of the liver, and occasionally the expectoration of blood-stained sputum.

Prognosis.—In true angina the prognosis for complete recovery is hopeless, the anatomical lesions not admitting of restoration. The patient is in constant danger. He may die in the first attack, or after several attacks. Unexpected prolongation of life occurs in some cases. The patient may not have a repetition of the early attacks and may possibly die of other troubles. A case reported by Murrell lasted forty years, and the elder Austin Flint believed that he had seen a case of actual recovery.

Treatment.—This resolves itself into the management, first, of the paroxysm, second, of the interval. When called to see a case during an attack the practitioner should always feel the pulse; this will generally but not invariably be found hard and tense, denoting high arterial pressure, which condition is usually present at the beginning of an attack. The first object of treatment is to lower the blood tension and relieve the strain on the heart. For this purpose the nitrite of amyl is still our most prompt and efficient weapon. This drug may be administered by inhalation, a few drops being placed on a handkerchief and held to the nose, increasing the dose carefully if necessary. Small pearls or capsules may be supplied to the patient with instruction to break and inhale in the event of an attack. Nitroglycerin acts in a similar manner to nitrite of amyl but is much slower. Its effects, however, are more lasting, usually extending over a period of from four to six hours. It is very useful in mild cases of vaso-motor angina and in pseudo-angina. The nitrite of sodium has an effect quite similar to that of nitroglycerin. If the arterial tension be found low and the pain still severe it is better to try the administration of a little chloroform or ether by inhalation, the former being, in the writer's opinion, most trustworthy. These agents must always be used by the physician or a trained attendant. A hypodermic injection of morphine is sometimes demanded. Yeo recommends the continuous current at the inception of a paroxysm. Mild cases may be relieved by antispasmodics and diffusible stimulants such as Hoffman's anodyne, musk, valerian, and assafœtida. Sinapisms or hot-water bags to the surface are sometimes helpful, and the same may be said of the quick application of the ice bag or cold cloths. During the intervals the underlying pathological state—arterio-sclerosis—should be combated by every available means. The iodide of potassium, strychnine, and arsenic form our main reliance. According to Balfour, arsenic is indicated in all heart diseases attended with pain. A most careful and discriminating mode of life is to be observed. All undue exposure and excitement should be avoided and the strictest self-control practised. *James K. Crook.*

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HEART DISEASES: SYPHILIS.—Syphilis of the myocardium manifests itself in the form of a local or diffuse fibroid myocarditis or as a gummatous myocarditis. The interstitial induration is by far the more common process; it may be the result of the direct action of the syphilitic poison or secondary to a syphilitic endarteritis. It occurs in both acquired and congenital syphilis, in the former case as a tertiary lesion. In its earliest stages the interstitial change is found as a cellular infiltration along the small vessels of the intermuscular connective tissue. Fibroblastic proliferation occurs in the latter, leading gradually to the formation of small scattered nodules of granulation tissue, which soon become converted into scar tissue. In the fibroid areas thus formed remains of degenerated muscle, pigment, fat droplets, etc., are found. The newly formed fibrous tissue may undergo caseation or become calcified. The neighboring muscle shows extensive atrophy and fatty degeneration. In other cases the cellular infiltration is in the form of bands or sheets running parallel with the axis of the muscle bundles. These may or may not be sharply defined; usually the new tissue sends out fine prolongations into the neighboring muscle. As the cellular infiltration develops it becomes gradually changed into a coarse hyaline variety of fibrous tissue containing few nuclei. Through atrophy of the intervening muscle the bands of connective tissue gradually coalesce and may come to make up the entire thickness of the heart wall from pericardium to endocardium. The left ventricle, the anterior wall, the apex, and the septum ventriculorum are most commonly affected, the papillary muscles and the walls of the auricles only rarely. In the congenital form the wall of the right ventricle is much more frequently affected than that of the left.

In the majority of cases the fibroid change is directly dependent upon the presence of an obliterating endarteritis in the coronary arteries. Complete occlusion of a terminal branch produces anæmic infarction, the necrosed muscle being replaced by scar tissue; slowly progressive obliteration of the vessels leads to degenerative changes in the muscle with secondary inflammation and proliferation of the interstitial tissue. To the naked eye the fibroid areas appear as white, glistening, tendon-like bands or masses. The weakening of the heart wall, due to the inability of the new connective tissue to contract against the intracardiac pressure, often leads to an aneurismal dilatation at the point of greatest change.

The gummatous form of myocarditis is of much less common occurrence. It is usually associated with a more or less diffuse interstitial change. It is probable that in many cases the fibroid myocarditis found at autopsy is the result of antecedent gummatous processes. Gummata may be found in any part of the heart wall, in the myocardium, or beneath the peri- or endocardium. To the naked eye they appear as yellowish or grayish cheesy nodules, varying in size from a mustard seed to a walnut, and are usually surrounded by a dense fibrous capsule. Fresh gummata are red or pink in color and of a soft homogeneous structure. They do not possess a fibrous capsule and are not sharply outlined from the surrounding tissue. Usually the heart gummata are solitary, but in many cases multiple caseous nodules are found scattered throughout the cardiac wall. When the gumma is located just beneath the peri- or endocardium chronic adhesive pericarditis and sclerosis of the endocardium are usually present. Hypertrophy and dilatation of the heart are frequent secondary changes dependent upon the myocardial condition. On microscopical examination the gummata of the heart are distinguished from those in other regions of the body by the cellular nature of the process, the rarity of giant cells, and the relatively slight degree of caseation. Obliterating endarteritis of the coronary arteries may or may not be associated with gummatous myocarditis.

Slight degrees of interstitial myocarditis and gummata of small size may give rise either to circulatory disturbances or to general symptoms. In the majority of cases the onset is slow and insidious, the symptoms of serious myocarditis developing only when extensive involvement of the heart muscle has occurred. Consequently sudden death from acute cardiac insufficiency is very common, occurring in two-thirds of the cases. In those cases which are observed for some time before death dyspnœa, venous stasis, ascites, and general œdema gradually developed without the presence of the physical signs of valvular disease. Extensive fibroid change or gummata of large size may lead to aneurismal dilatation of the heart wall, general hypertrophy, or dilatation accompanied by the gradually developing symptoms of cardiac insufficiency. Rupture of a softened gumma into the blood stream very frequently leads to thrombosis and embolism. In the reported cases the emboli were found in the vessels of the retina and choroid, and in the coronary and pulmonary arteries. A form of syphilitic angina pectoris has been described by some writers who have attributed it to a specific action of the syphilitic poison upon the neuro-muscular apparatus of the heart wall or upon the sympathetic nerves. The progress of cardiac syphilis is usually very slow, periods of apparently good health may alternate with extended attacks of cardiac insufficiency. In either period slight accidents may cause sudden death. This may be due to rupture of the heart or to occlusion of the coronary arteries, either through fibroid changes, or through thrombosis or embolism.

The diagnosis of syphilitic disease of the heart rests upon the exclusion of other causal factors and the establishment of the existence of a syphilitic infection, either past or present. In doubtful cases the therapeutic test should be employed. The prognosis in undoubted cases of syphilitic myocarditis is very unfavorable if the condition is well advanced. Only in the earliest stages, before much structural change of the heart wall has occurred, is there hope of a cure. The treatment is that pursued in cases of syphilis in general, with special treatment directed to the myocardial condition. It is very probable that systematic treatment of all cases of syphilis, if continued faithfully for four or five years, would greatly diminish the number of cases of myocardial syphilis. *Aldred Scott Warthin.*

HEART DISEASES: TUBERCULOSIS.—Tuberculosis of the myocardium is very rare. The first recorded case is that of Townsend in 1832. In 1894 Valentin collected thirty-six cases from the literature, and estimated that the condition occurred but once in one thousand tuberculous bodies. Hand, in 1898, collected forty-two cases, and in 1899 Thiry was able to gather sixty-three cases from the literature up to that year. With the exception of a few cases the condition was secondary to tuberculous disease elsewhere in the body. Demme and Knopf have reported cases thought to be primary. The majority of the cases occurred before the fifteenth year, several in infants. The ventricles are more often affected, the wall of the right auricle next in frequency. In the majority of cases the lesions are characterized by the scarcity of tubercle bacilli found in them.

The infection of the myocardium occurs either by direct extension from the pericardium or endocardium, or by hæmatogenous or lymphogenous metastasis. According to some writers a retrograde lymphogenous metastasis from the bronchial lymph glands forms the most common means of infection. This is denied by others, inasmuch as the lack of collateral anastomosis of the cardiac lymph vessels does not favor retrograde metastasis. In the miliary cases the avenue of infection is usually through the veins.

The disease may manifest itself in several forms: (1) Scattered miliary nodules through the muscle; (2) large caseous nodules varying in size from a pea to a hen's egg, usually multiple, but occasionally single; (3) diffuse tuberculous myocarditis in the form of a fibroid change with scattered caseous nodules of small size; (4) fibroid myocarditis with small non-caseating tubercles. The third and fourth forms are very rare; and are with difficulty distinguished from syphilitic processes, as the bacilli are found in such scanty numbers as to be very difficult of demonstration. The miliary tubercles are usually most numerous just beneath the epicardium, occasionally beneath the endocardium. They rarely extend far into the muscle. The large caseous tubercles represent a more chronic infection; they may be encapsulated or show extensive signs of healing. In these cases the pericardium is almost always involved, the endocardium only rarely when the lesion is in the ventricles. In the case of a tubercle of large size developing in the auricular wall both peri- and endocardium are soon involved. Perforation into the auricular cavity may take place and give rise to a general miliary tuberculosis. In a case reported by Püschmann there was an acute miliary tuberculosis which seemed to have taken its origin from a thrombus containing numerous tubercle bacilli which was attached to a caseating tubercle in the auricular wall.

With slowly developing tubercles there is always associated an interstitial myocarditis. In the case of the large caseous tubercle this process is confined to its immediate vicinity. This form of interstitial myocarditis is much less important than the diffuse form associated with scattered tubercles of slow growth and showing little tendency to caseate. In spite of the weakening of the cardiac wall through replacement of the muscle by connective tissue and through caseation of the tubercle, a rupture or aneurism of the wall is not likely to occur in these cases because of the diminished blood pressure. In none of the recorded cases of myocardial tuberculosis has this event been observed. Further, there is usually extensive fatty degeneration of the heart muscle in the neighborhood of the tuberculous process, and this diminishes to a still greater degree the efficiency of the heart's action. Calcification or encapsulation of the caseous tubercles may occur here as elsewhere. Complete healing may result, the tubercle being wholly replaced by connective tissue.

Within very recent years the presence of tubercle bacilli in parietal thrombi and endocardial vegetations has been many times demonstrated, and it is very probable that tuberculous endocarditis is of much more frequent occurrence than is usually supposed. The great frequency of cardiac thrombi in pulmonary tuberculosis suggests the possibility of their formation by the lodgment of bacilli upon the endocardium. Secondary involvement of the myocardium may follow the development of such endocardial tubercles.

Tuberculosis of the myocardium presents no characteristic symptom complex, and in the great majority of cases cannot be diagnosed. The symptoms depending directly upon the condition would be those of a myocarditis. Involvement of the pericardium may give rise to such definite signs and symptoms as to permit of the diagnosis being made. In case of pericardial effusion a bacteriological examination of fluid obtained by puncture could be made. The termination of the cases is by death, due usually to the general tuberculosis rather than to the condition of the heart. Rarely solitary tubercles of small size and slow growth may heal. For the great majority of the cases there is no treatment beyond that of a purely symptomatic nature. *Aldred Scott Warthin.*

HEART DISEASES: VALVULAR LESIONS.—GENERAL ETIOLOGY.—The great majority of cases of chronic valvular lesions originate in acute or chronic endocarditis. A single attack of acute rheumatism may leave the valves in a seriously damaged condition, but more frequently contraction and thickening of the valvular apparatus continue after the acute stage has passed off, and the leaflets gradually become deformed and defective in function. Recurring attacks of endocarditis are liable to occur in valves once damaged by this cause, and slight defects may thus terminate in serious and irreparable injury.

Valvular deformity may also originate in a chronic sclerotic process, comparable to the changes which take place in sclerosis of the vessels. Although this chronic process may originate from rheumatic influences, yet there are a number of causes which, when taken collectively, exert a more frequent influence.

That high arterial pressure is capable of producing valvular lesions is shown very clearly by the experiments of Roy and Adami. These observers narrowed the aorta of the dog by clamping and thus induced a fringe of swollen tissue at the free edge of the valve, due to infiltration of cells and œdema.

Clinically it is well recognized that long-continued high arterial pressure may result in sclerosis and thickening of the valves. More particularly is this noticed in the aortic segments which have to bear the brunt of increased strain in the arterial system; the mitral cusps often suffer as well, and thickening of their free borders is very frequent in cardiac hypertrophy, a condition in which they are subjected to increased strain.

The proportion of cases originating in acute and in chronic endocarditis, has been variously estimated. It is more common to trace an origin in acute endocarditis, resulting from rheumatism or other infectious processes, in the mitral than in the aortic segments. In aortic lesions the process is frequently chronic from the outset.

Guttmann regards three-fourths of all valvular cases as beginning in a chronic fashion, and Worobjew's (*Deut. Arch. f. klin. Med.*, 69, 466) analysis of 180 cases also confirms this view. Most writers have, however, regarded the rheumatic cases as the most frequent; Schott attributes 54 per cent., and Gibson 63 per cent. of cases to a rheumatic origin.

AORTIC INCOMPETENCE.—*Etiology.*—Although occurring at all ages and in both sexes, it is far more commonly met in males about the middle period of life. Under the age of twenty-five most cases are due to a rheumatic origin, and in these it is usual to find the mitral valve also affected. Anatomically, a large majority of cases originate in a chronic fibrosis of the segments of the valve with resulting retraction and deformity. All conditions leading to continued or even intermittent high pressure tend to the development of fibroid thickening. Incompetence is consequently often seen in arterio-sclerosis, chronic Bright's disease, gout, plumbism, and in chronic alcoholism. Those engaged in laborious physical work constitute the greater number of cases. It is consequently frequent in laborers, and is occasionally seen in athletes. Old soldiers often suffer from the disease, owing partly to laborious physical exertion, partly to chronic alcoholism and to specific infection, which has a well-marked but obscure relation to the disease. Tabetics are not infrequently attacked by aortic insufficiency, a fact attributed by Gowers to a common origin in syphilis. Owing to the frequent involvement of the coronary vessels in the sclerotic processes at the root of the aorta, the arterial cases are usually more serious than those due to stationary rheumatic endocarditis.

Morbid Anatomy.—In the great majority of cases aortic incompetence is due to a chronic sclerotic process in the valves. Their free edges become thickened and retracted, and the cusps fail to support a column of water when poured into the aorta. Their edges frequently adhere to each other, causing more or less obstruction. Patches of atheroma are often present on the valves, and in old-standing cases there may be an abundant deposit of lime salts, giving a hard bony feel to the margins of the orifice. When extreme adhesions and stenosis are present, a transverse bar is sometimes seen running from the united cusps to the wall of the aorta, and represents the margins of the original segments. The mitral valve is frequently involved in the sclerotic process, particularly in the rheumatic cases. The root of the aorta often presents atheromatous and calcareous plates and in many instances it is dilated. Freshly raised atheromatous plaques in the aorta, involving one or more of the aortic segments, are occasionally met with. Fresh endocarditis is frequently added on to older lesions, and it is not uncommon to find a row of warty granulations along the edge of the valve. Vegetations are found in the course of acute rheumatism and in malignant endocarditis. They may interfere mechanically with the closure of the valves, or in the latter instance cause incompetence from rupture of one of the segments.

Dilatation of the root of the aorta, the result of atheromatous changes, is a rare cause of aortic insufficiency. A series of cases has been recorded by Pitt (Trans. Path. Soc., 1898) in which incompetence was induced in this way, without marked changes in the valve. In aneurism it is very common to find aortic regurgitation, but in such cases it is usually due to a coexisting sclerotic change in the valve. With advancing age the aortic orifice becomes wider, but the comparative rarity of aortic incompetence in old people would seem to indicate that the dilatation is insufficient to allow of regurgitation.

Osler (Trans. Am. Phys.) has pointed out the frequency with which sclerosis and insufficiency occur in those cases of malformation in which two, instead of three cusps, exist.

Rupture of the aortic cusps occurring spontaneously, or more commonly from violent efforts, or as the result of severe direct injury to the chest has been recorded in a number of instances, and is a rare cause of aortic incompetence. Barié has shown that rupture may be produced experimentally, and that the aortic cusps suffer more readily than other valves. Although perfectly healthy valves may suffer in this way, yet in most instances there is evidence of previous sclerotic change. The average age at which rupture occurs is thirty-nine, a period of life at which degenerative changes are common, and is suggestive of previous disease.

Important secondary changes take place in the cardiac chambers as the result of aortic incompetence. The left ventricle is obliged to accommodate not only the usual amount of blood from the auricle, but also that which regurgitates during diastole of the ventricle. The consequence is that this chamber becomes dilated to an extent corresponding with the volume of blood passing from the aorta, and the degree to which dilatation takes place is thus an index to the extent of regurgitation. In the severer types of the disease dilatation is extreme, and the heart reaches a size seldom attained under other circumstances, *the cor bovinum.* Although dilatation is primary and the cavity remains greatly enlarged, some hypertrophy of the ventricular wall also results, and thus balances or compensates for the diseased valve. Owing to the difficulty it experiences in propelling blood into a ventricle already distended, the auricle in turn dilates and hypertrophies, and eventually the right heart becomes involved as in mitral disease.

Symptoms.—This lesion is most frequently discovered during the routine examination of patients in apparent health, or in the subjects of other maladies. Compensation is often well maintained for years, and during this period there are few or no subjective symptoms, and indeed there is usually much less discomfort than in mitral lesions. Dizziness, palpitation, and precordial pain are sometimes noticed, and dyspnœa on exertion is often an early symptom of failing compensation. The facies presents in many instances a pale and anxious aspect, contrasting with the cyanosis of mitral affections.

An exception to the insidious onset is seen in cases of ruptured valve. Here the abrupt onset with severe precordial pain and dyspnœa, the development of a diastolic murmur, sometimes so loud as to be perceptible to the patient himself, the occurrence immediately or shortly after some unusual strain or external violence to the chest, form a clinical picture which is very striking. The severer cases may terminate fatally in a few weeks, but for the most part they survive for a longer period. Two of Barié's cases lived for eleven and thirteen years respectively.

Failing compensation is marked by dyspnœa, palpitation, and swelling of the feet. Dyspnœa, as in other forms of cardiac disease, comes on from exertion, especially in mounting a hill or climbing a stair. As the malady advances there are often attacks of paroxysmal dyspnœa, coming on especially at night, and known as cardiac asthma. Loss of sleep and a moderate loss of flesh give the patient a worn and anxious aspect. Œdema, if present, is usually moderate in extent, except in advanced cases in which there is secondary mitral incompetence, when it may attain a high grade.

Pain is more commonly present in aortic than in other valvular lesions. It varies much in intensity, from a sense of weight and uneasiness to acute pain, often radiating to the left arm and shoulder, seldom to the right. In arterio-sclerotic cases, in which the coronary arteries are involved, all the characters of true angina may be present.

In advanced stages of the disease orthopnœa and Cheyne-Stokes breathing, either with or without general anasarca and the visceral congestion of mitral lesions, may be present.

Mental disturbance develops more commonly in aortic than in other valvular affections, and shows itself in restlessness and change of temper. In some instances delusions are prominent and the patient may require restraint.

The symptoms in many instances are dominated by those of arterio-sclerosis or chronic renal disease, in which the incompetent valve is merely an incident. Sudden death is an accident which may ensue even in apparent health. Such an occurrence is more liable to happen when there is disease of the coronary vessels. Death occasionally comes rather unexpectedly after the symptoms of ruptured compensation have lasted for some time, but the more common termination is by gradual failure, dropsy, and asystole.

Physical Signs.—Visible pulsation in the arteries often suggests the existence of aortic incompetence. Throbbing of the carotids, visible pulsation in the radial and temporal arteries, and, in severe cases, even in the digital branches of the hands and feet are distinctly seen. Pulsation of the palate and uvula has been observed, and the pulse may be counted in the retinal arteries with the ophthalmoscope. Capillary pulsation is seen in the finger nails, and is also readily observed in the lips when a glass slide is pressed on them. The pulse has certain characters which at once reveal the nature of the affection to the practised finger. The wave is large, it strikes the finger suddenly and as rapidly recedes, these characters being more marked when the arm is raised. Since the appearance of Corrigan's paper, this pulse has gone by his name, and is also known as the water-hammer or collapsing pulse. It is regular in volume and rhythm except in the later stages, when slight irregularity may develop. The arteries are frequently thickened and this feature is seen even in young people suffering from the rheumatic form of the disease.

Examination of the heart shows the presence of very distinctive signs, the more important being the increased size of the organ and the diastolic murmur at the base. These signs, taken in conjunction with the arterial phenomena, render the affection one of the easiest of cardiac lesions to recognize.

Inspection often shows a slight degree of fulness in the cardiac region, particularly in children and young adults, in whom the chest wall is more elastic. Visible pulsation is seen below and outside the normal apex site, and retraction may be seen in the third and fourth spaces due to atmospheric pressure during systole.

On palpation the cardiac impulse is forcible and heaving, and the apex is felt in the nipple line or as far out as the mid-axilla, in the fifth, sixth, or even the seventh space. The increased area of the heart is also shown by percussion, the dulness extending down and to the left side.

The most characteristic sign is found on auscultation in a diastolic murmur, due to the reflux of blood to the ventricle. It is usually a soft prolonged souffle, beginning with the second sound, and occupying the greater part of the diastolic interval; it is sometimes shorter or its character may be harsh. Although sometimes having its site of maximum intensity at the aortic cartilage, it is usually best heard about the pulmonary region. It is transmitted down the sternum, especially to its left side, and is occasionally heard only at the lower sternal region. It is frequently transmitted to the apex, and when loud is heard all over the front and back of the chest. The diastolic murmur in question is one of the most persistent of cardiac murmurs. It occasionally disappears during periods of asystole, to reappear with increasing cardiac power. Instances have been reported in which the murmur disappeared from closure of the orifice by a vegetation, and Musser has recorded a remarkable case in which the leak ceased owing to wearing down of the thickened corpora Arantii. A systolic murmur commonly precedes the diastolic sound, and with it gives the well-known to-and-fro murmur.

The second sound is often dull and indistinct and may be entirely lost. When absent it indicates serious deformity of the valve segments and is usually a sign of extensive regurgitation. The sound should be listened for in the arteries of the neck, as it may be present, but obscured by murmurs at the base of the heart.

The gradual development of aortic incompetence may sometimes be traced from an accentuated second sound in arterial sclerosis to the diastolic murmur of the incompetent valves.

A presystolic murmur at the apex was first described by Flint in cases of aortic incompetence, and commonly goes by his name. It exactly resembles the rumbling murmur heard in many cases of mitral stenosis. Thayer in a recent study of this murmur states that it was present in sixty per cent. of his cases, and that thrill, snapping first sound, and the tapping impulse of mitral stenosis were also occasionally noticed. The pulse characters form the best guide in distinguishing the two conditions, but when they are combined it is often difficult or impossible to state whether the murmur is associated with mitral stenosis or is due to aortic incompetence.

The temperature in cardiac disease is usually subnormal. Elevation of temperature is sometimes the first evidence of a fresh endocarditis. It may, however, signify some rheumatic or other inflammatory complication. In the advanced stage of cardiac disease it is most often due to a broncho-pneumonia, and is frequently seen a few days preceding death.

Diagnosis.—The physical signs of a well-marked case of aortic incompetence are unmistakable. The diastolic murmur is a very constant feature, only seldom disappearing in advanced cases with asystole. Temporary diastolic murmurs are occasionally heard in arterio-sclerosis, the valve probably yielding to the increased blood pressure. Allbutt regards such cases as the early stage of the affection. A diastolic murmur is sometimes heard in mitral stenosis at the pulmonary area, and represents a temporary incompetence of the pulmonary leaflets from increased pressure in this vessel. Such a murmur is distinguished by the small pulse of mitral disease, instead of the large collapsing pulse of aortic incompetence.

The degree of regurgitation is estimated by the size of the ventricle and the character of the pulse. Disappearance of the second sound at the base and in the arteries of the neck also indicates free regurgitation.

AORTIC STENOSIS.—*Etiology.*—Although occurring at all ages, and sometimes as the result of changes in early life, aortic stenosis is most common in old men with calcareous arteries.

In high degrees of the affection the valves are thickened and calcareous and the orifice may become so narrowed as hardly to admit a probe. In rare cases the obstruction is subvalvular and the result of an attack of fœtal endocarditis. Stenosis, apart from the slighter grades of the affection, and unassociated with aortic incompetence, is a rather rare condition.

The symptoms are similar to those found in aortic regurgitation, and depend rather on associated conditions, such as generalized arterio-sclerosis, sclerosis of the root of the aorta, disease of the coronary vessels, and myocarditis, than on the aortic lesion itself.

The onset of the affection is insidious, and there is a long period of latency. Uneasiness or pain in the cardiac region, sometimes assuming the characters of true angina, cardiac oppression, palpitation and dizziness, dyspnœa and syncopal or even epileptic attacks, may be amongst the earlier symptoms. In the later stages dilatation of the left ventricle takes place and relative mitral insufficiency ensues. Dropsy and the usual evidence of venous stasis set in, and the clinical picture assumes the type seen in the more advanced stages of mitral disease.

The diagnosis rests on the physical signs. The peripheral arteries are usually thickened and calcareous, whilst the characters of the pulse afford valuable evidence of the nature of the lesion. It is small, often of high tension, the upstroke is slow and gradual, the wave is well sustained and it falls away slowly. These features are well shown in a sphygmographic tracing; the upstroke is oblique and is sometimes interrupted by an anacrotic notch, like the dicrotic notch in the down stroke. This notch has been regarded as a double effort on the part of the ventricle during systole, but it occurs in other conditions and has no special diagnostic significance; the apex of the curve is rounded and the downstroke gradual. The pulse rate is often infrequent, falling to 60 or below. (*Vide* Clin. Soc. Trans., 1897.)

Evidence of hypertrophy of the ventricle is present, but the enlargement does not reach the degree seen in aortic incompetence. Inspection and palpation reveal an apex beat below and outside the normal site, with a strong heaving character. Emphysema of the lungs, however, is frequently present and prevents the apex site from being determined, rendering it weak and indistinct. Under these circumstances cardiac dulness is often lessened. A systolic thrill about the aortic cartilage is commonly present; it is often well marked and of great intensity, and is sometimes transmitted to the vessels of the neck, or felt in the episternal notch. With failing cardiac power the thrill may lessen or disappear. On auscultation a rough harsh murmur is heard in the aortic region, occasionally having a musical character. It is prolonged through the whole of systole, often completely obscuring both sounds of the heart, the second being lost from the rigid character of the valves. It is best heard about the aortic cartilage and transmitted to the vessels at the root of the neck. It is heard over the cardiac area with diminishing intensity toward the apex, and in many cases it is so loud that it is heard all over the chest and even at a short distance from the patient. In the terminal stages of the malady, with failing cardiac action, the murmur may lose something of its intensity and roughness.

Diagnosis.—A common error is to regard all aortic systolic murmurs as due to stenosis. Murmurs in this region are most frequently due to atheroma of the root of the aorta, to slight sclerotic changes in the valves, or they are of a functional character. They are then often less loud and rough than in cases of stenosis. Coarse atheromatous changes in the aorta may, however, cause both a rough murmur and a thrill, and it may prove difficult or impossible to distinguish such a condition from true stenosis. An accentuated second sound is common in atheromatous states, and is not likely to be present in stenosis, owing to the rigid state of the valves.

The peculiar characters of the pulse, the marked characters of the murmur, and the presence of thrill form a combination of signs which are highly characteristic, and, when distinct, are unmistakable.

Mitral Incompetence.—This may result from acute or chronic endocarditis, from rupture of the chordæ tendineæ, or from dilatation of the ventricle preventing the apposition of the valve segments.

In young people a large proportion of cases originate in acute endocarditis; hence the frequency with which a history of acute rheumatism occurs in the clinical history. It is by no means infrequent to obtain no history of rheumatic conditions, even in children and young people, whilst in older individuals a chronic sclerotic process is often the primary change.

The mitral valve is much more liable to rheumatic inflammation than the aortic, and in fact the latter valve seldom suffers from this cause without involvement of the former.

In malignant endocarditis, rapid ulceration or necrosis of the valves, or rupture of the chordæ, is occasionally responsible for serious destruction of the valve. Rupture of the chordæ also occurs, apart from acute endocarditis, as a result of strain or external violence, although such cases are very unusual. Cardiac dilatation, resulting from strain or from myocardial changes, often produces relative mitral incompetence, even with perfectly healthy valves. This condition is frequent as a temporary manifestation in the acute dilatation of infectious disease and in anæmia. In aortic lesions and in chronic dilatation or myocarditis, incompetence occurs owing to this mechanism.

Morbid Anatomy.—The changes in old-standing cases consist in thickening and rigidity of the valvular segments. In cases due to endocarditis, there is almost invariably some degree of narrowing. The orifice is naturally wider than normal when relative incompetence is present.

Secondary changes of a compensatory character take place in the various cardiac cavities. The left auricle dilates to accommodate the extra current of blood passing through the leaking valve, and also hypertrophies to cope with the increased work thrown upon it. The ventricle undergoes similar changes, being stimulated by the increased flow from the left auricle. The circulation in the pulmonary circuit is impeded by the overfilled auricle, and in consequence the right ventricle, and ultimately the right auricle, dilate and hypertrophy.

The tricuspid orifice, owing to dilatation, may become incompetent, a feature which accounts for certain clinical phenomena in the advanced stage of the affection. Sclerotic changes occasionally occur both in the trunk and in the smaller branches of the pulmonary artery, owing to the increased blood pressure.

A deposit of fibrin amongst the musculi pectinati or chordæ tendineæ is seen in the dilated cardiac chambers, and forms the usual source of emboli.

Venous stasis in the various organs is frequent in mitral lesions. The lungs are affected earliest, and undergo the change known as brown induration. The capillaries are overfilled and consequently thrown into loops, whilst blood pigment passes to the alveolar walls, and a slight increase of interstitial tissue, the result of chronic congestion, takes place. The epithelial lining in the alveoli is somewhat swollen, and contains specks of pigment.

Hemorrhagic infarcts are common in the advanced stages. They are often attended by hæmoptysis and a localized pleuritis. Œdema of the lungs and hydrothorax are frequent as manifestations of part of a general dropsy, and a terminal broncho-pneumonia is a common cause of death.

The liver shows dilatation of the radicles of the hepatic veins in the centres of the lobules, with an exudation of pigment in the surrounding cells, whilst the periphery of the lobule undergoes fatty changes owing to deficient oxygenation. To the naked eye the cut surface presents a mottled appearance, the dark-colored centres contrasting with the pale peripheral portions of the lobules, and giving the organ the name of the nutmeg liver. When congested it is enlarged and extends below the costal border, and in the later stages fibroid changes may supervene, the organ becoming indurated and uneven on the surface, a condition known as cardiac cirrhosis.

Somewhat similar changes take place in the kidneys; these organs are enlarged and congested in the earlier stages, and eventually may terminate in cirrhosis and contraction.

Œdema and congestion of the gastro-intestinal tract, and subcutaneous œdema with effusion into the serous sacs, are also present in the advanced stages of the affection.

Symptoms.—These vary greatly according to the character and stage of the disease.

In acute endocarditis the development of a mitral incompetence is revealed only by the physical signs; dropsy and dyspnœa are only exceptionally present even in the graver forms of endocarditis, and the clinical picture is that of the primary infectious process. In chronic cases compensation may be maintained for a long period, even when the serious nature of the lesion is shown by a greatly enlarged heart and an apex murmur. Although some individuals pass through a long life with little or no discomfort, it is more usual to find some dyspnœa on exertion. The facial appearance is often suggestive. The lips and cheeks may be of a deeper tinge than usual, the veins of the neck are distended, and there is stellate enlargement of the veinules of the cheeks, and occasionally clubbing of the finger nails. Attacks of palpitation are often induced by exertion, but they may also result from flatulence. A dry hacking cough or recurring attacks of bronchitis are frequently found.

Amongst the graver symptoms are a weak, irregular pulse, dropsy, and increasing dyspnœa. Breathlessness is brought on by even slight exertion, ultimately becoming constant even at rest. The respirations are deep and labored, accompanied by contractions of the extraordinary muscles of respiration, and the patient rests propped up by pillows, or leaning forward in an armchair. Attacks of Cheyne-Stokes breathing are often seen, or again paroxysms of dyspnœa, often occurring at night and interfering with rest.

Accompanying the dyspnœa is œdema, which begins about the feet and ankles, noticed first after being up, and disappearing with a night's rest. Unless checked by suitable treatment it gradually increases, and extends to the thighs, scrotum, and serous sacs. The face remains free, but the upper extremities sometimes share in the progressing œdema. The œdema is firm and hard, and is accompanied by coldness and cyanosis of the extremities, and lividity of the face. When the abdomen becomes distended with fluid it still further embarrasses the breathing.

Hydrothorax is usually bilateral, but in some instances occurs chiefly on one side. In some cases the dropsical effusion affects principally the serous sacs, particularly the peritoneum, and requires periodic removal. It sometimes collects with extraordinary rapidity, after a period of absence.

Sleeplessness, starting from sleep, and bad dreams occasionally occur, even apart from the severer symptoms of failure of compensation.

Of the various organs the liver is enlarged and somewhat tender, frequently reaching as low as the umbilicus. A slight tinge of jaundice is very common, and bile may be detected in the urine. The secretion of urine is greatly diminished, sometimes falling to three or four ounces, or even being suppressed. It is of high specific gravity, it deposits a sediment of urates, and shows albumin in small or moderate quantities, and often granular and hyaline casts. With the disappearance of dropsy diuresis sets in, and the urine may run up to two or three times its normal quantity, with disappearance of albumin, and later of casts. Gastric symptoms such as flatulence, and sometimes nausea and vomiting, are not uncommon.

With appropriate treatment dyspnœa and œdema may disappear, and the patient be restored to comparative health. Sooner or later, however, the same symptoms recur, particularly in individuals who are unable to obtain the necessary rest. It is frequent to find several such attacks before the fatal issue.

Eventually a period is reached when the heart, either in consequence of extreme dilatation or of myocardial degeneration, fails to respond to treatment. The terminal illness is frequently very prolonged, and for several months the unfortunate individual struggles with dyspnœa and dropsy, and eventually succumbs to exhaustion.

Physical Signs.—The most characteristic sign is a systolic murmur, heard best at the apex. It is variable in character, being sometimes loud and bellows-like, sometimes having a musical character, or again being extremely soft and distant. Faint systolic murmurs at the apex also occur with slight defects in the valve, and in conditions of temporary dilatation, whilst a loud bellows or a musical murmur usually indicate more definite changes in the valve. The murmur of incompetence may, if faint, be localized at the apex, but it is usually transmitted to the axilla, or heard in the back at or above the angle of the scapula; it is often heard up to the pulmonary cartilage and near to the ensiform, and it may even have its site of maximum intensity at the pulmonary area. The first sound is often obscured or replaced by the murmur, whilst the second sound is accentuated at the pulmonary area. With failing power of the right ventricle accentuation disappears, and is thus of unfavorable omen.

A thrill is of the rarest occurrence in mitral incompetence. When there is any considerable degree of regurgitation there is enlargement of the left ventricle. The impulse is strong and heaving, and lies in a line with, or outside the nipple; a well-marked epigastric pulsation is often present owing to hypertrophy of the right ventricle. As dilatation or weakness supervenes, the impulse becomes weak and diffuse. Fulness and distention are sometimes seen, particularly in the yielding chest walls of children. Percussion shows an increase in dulness to the left and often to the right, reaching the right sternal border or even the parasternal line. Upward, dulness often begins a space higher than normal.

Diagnosis.—It is not uncommon to find a systolic murmur at the apex in the absence of any other sign of cardiac disease. Its chief importance is the mental disquietude it may cause in nervous patients, and the unfavorable light in which it is usually regarded by life insurance companies. Such murmurs are sometimes evidence of slight valvular damage, but in the absence of symptoms and of other signs of disease, such as enlargement and pulmonary accentuation, they may be disregarded. A murmur heard toward the end of inspiration, and attributed to the entry of air into the pulmonary vesicles during systole, is not uncommon, and is known as the cardio-respiratory murmur. It has usually no cardiac significance. It is not always possible to distinguish regurgitation due to a valvular lesion from that of muscular dilatation. In elderly individuals, in Bright's disease or arterial sclerosis, or in anæmia, the latter condition may be suspected. A history of rheumatism, on the other hand, suggests endocarditis. In some instances, as in anæmia and in acute dilatation from strain or infectious fevers, any doubt is often cleared up by the gradual disappearance of the morbid signs.

Mitral Stenosis.—Narrowing of the mitral valve is for the most part a disease of the first half of adult life, often starting from an acute endocarditis in childhood. It is much more common in females, owing doubtless to the greater frequency of rheumatism in young girls than in males of the same age. Although the lesion is often regarded as of purely rheumatic origin, it is remarkable how often a history of acute rheumatism is absent. In children, however, rheumatism, as pointed out by Cheadle, is frequently an ill-marked condition, the articular manifestations being slight, or replaced by such symptoms as tonsillitis, growing pains, or erythema, and yet in these apparently slight cases severe forms of endocarditis may develop.

Cases of mitral stenosis are occasionally found in a first attack of acute rheumatism, a fact strongly suggestive of an old-standing latent rheumatic influence. An absence of a history of acute rheumatism is therefore no evidence of a non-rheumatic origin.

Mitral stenosis is occasionally found in arterio-sclerotic cases and in interstitial nephritis, a fact which has suggested an arterial origin for some of the cases. In 542 autopsies, in cases of interstitial nephritis, Pitt found mitral stenosis 33 times, and other writers have recorded the association of the two conditions.

In most if not all instances of rheumatic endocarditis, there is some narrowing of the mitral orifice, but it is only when this is considerable that the signs become distinct.

Anatomically the valve curtains are rigid, thickened, and adherent; and form a diaphragm perforated by the mitral orifice, which is reduced to a narrow slit-like opening, often termed the "button-hole" orifice. Less commonly the valves project in a funnel-shaped fashion toward the ventricle. The chordæ tendineæ are thickened and adherent, whilst a deposit of calcareous salts is frequent in the valve and even in the chordæ themselves.

The secondary changes are seen first in the left auricle which becomes hypertrophied and often dilated. According to Samway's observations hypertrophy is the primary change, dilatation occurring later. He found that cases of stenosis dying from cardiac failure presented, in addition to hypertrophy, a marked degree of dilatation, whereas those dying from surgical diseases or affections apart from the heart usually showed hypertrophy only.

The state of the left ventricle varies greatly. Theoretically it is argued that the diminished quantity of blood passing through the narrowed orifice cannot induce hypertrophy or dilatation, and that the ventricle remains of normal size or even undergoes a certain degree of atrophy. This view is certainly correct for some cases; at the same time hypertrophy is seen in a considerable proportion of cases, and according to Baumbach, who enters into this question very fully, a moderate degree of hypertrophy is present in almost all cases. Mitral regurgitation may be regarded as responsible for this hypertrophy in some instances, whilst in others there are pericardial adhesions or arterio-sclerosis. The cavities of the right side undergo a marked degree of dilatation and hypertrophy, and the contrast between the enlarged right ventricle and the small left is sometimes very striking.

Symptoms.—Some degree of dyspnœa is almost always present on exertion, and this with palpitation may continue for years. When the disease dates from childhood there is frequently a stunted growth, the chest is ill-developed, and there is diminished physical and mental vigor. The lips are often of a deep blue tinge, and in old-standing cases there is sometimes clubbing of the nails of the fingers and even of the toes.

As compensation fails dyspnœa becomes more and more troublesome, and signs of venous stasis similar to those seen in mitral incompetence are found in the various organs. Pulmonary symptoms are common and these patients are very subject to recurring attacks of bronchitis.

Attacks of hæmoptysis occasionally occur, and, unless due to infarction, often have a beneficial effect, relieving pulmonary congestion and the embarrassed right heart. Other signs of venous congestion are observed in recurring attacks of epistaxis from which some patients suffer, whilst hemorrhoids or menorrhagia occur in others.

Dropsy of the extremities is seldom a prominent feature, and any œdema present is usually slight. Signs of a venous obstruction often fall chiefly or exclusively on the portal system, and hepatic enlargement or even cirrhosis may be present with ascites, in cases which show little or no œdema of the lower extremities.

Welch (Trans. Am. Phys., 1900) has recently called attention to venous thrombosis in cardiac disease, occurring in serious failure of compensation, and more particularly in mitral stenosis. The veins affected are most frequently those conveying blood from the neck and upper extremity, and more commonly on the left than the right side. The peculiar localization of the thrombosis is to be attributed to the greater length and obliquity of the left innominate vein, and to pressure, direct or indirect, on the left subclavian vein from the dilated left auricle and pulmonary veins.

Symptoms of ruptured compensation often first appear during pregnancy or labor, or follow parturition: alarming or even fatal attacks of pulmonary œdema sometimes appear, or persistently rapid action of the heart leading to asystole. Pregnancy is a complication in which there is always serious risk, although in favorable cases there is little or no disturbance. Subsequent pregnancies are sometimes passed without special difficulty, when earlier ones had caused great disturbance.

Hysterical manifestations are not uncommon in the course of mitral stenosis, both conditions being common in young women. Cardiac symptoms often predominate, and severe attacks of pseudo-angina, of palpitation, or of dyspnœa may occur in well-compensated cases. Without a correct appreciation of the neurotic element in such individuals these symptoms may lead to undue alarm.

Embolism is more common in this than in other forms of valvular lesions. If it occurs in the brain this accident shows itself in the form of hemiplegia, and if the embolus lodge on the left side, there will be aphasia.

The physical signs when well marked are extremely characteristic, but in the advanced stage of the disease they are often indefinite or equivocal. The more important are: the presystolic thrill and murmur, the snapping first sound, the accentuated pulmonary second, and evidence of enlargement of the right heart.

The pulse is small, somewhat increased in rate, and often of good tension; it is usually regular until a late stage of the malady, when extreme rapidity and arrhythmia may set in. The thrill, which is one of the most characteristic signs of the disease, is felt at the apex, and when the heart is not unduly rapid it is readily made out distinctly to precede the systolic impulse. It is sometimes prolonged, running through the whole diastolic interval, or it may immediately precede the impulse, and is then strictly pre-systolic. When present it is pathognomonic of stenosis. The cardiac impulse often gives the impression of a jet of liquid being projected against the hand. The murmur in typical cases is loud and rough, and is commonly compared to the sound "rrrb." It runs up to and terminates in a loud, abrupt, and snapping first sound. The murmur may be prolonged through the diastolic interval, but in the great majority of instances it occurs at the end of this period. In either case it is usually spoken of as the pre-systolic murmur. The murmur is in most instances localized at or about the apex, although, as pointed out by Griffiths, it is sometimes transmitted to the axilla or even heard in the back. The murmur is sometimes represented by a mere rumble, and in the absence of the snapping first sound is easily missed by the untrained ear. With advancing cardiac weakness both thrill and murmur often disappear. A systolic murmur is frequently present, due to associated incompetence. It may persist when the thrill and murmur have disappeared.

Hardly less characteristic than the murmur is the abrupt snapping first sound in which it terminates. It is often mistaken for the second sound, but the distinction can be made by noting that it is synchronous with the apex impulse. The second sound is often lost at the apex, and is sometimes reduplicated at this region; in the pulmonary area it is accentuated and even ringing, losing these characters with failing power in the right ventricle. With high tension in the pulmonary artery, a faint, whiffing, diastolic murmur is occasionally heard. This is regarded by Gibson and others as due to a temporary incompetence at the pulmonary orifice.

Evidence of enlargement of the right heart is often present, as shown by the increased impulse over the lower sternal region, and by an extension of dulness to the right border of the sternum or beyond, reaching in extreme cases as far as the right nipple line. With failing compensation and particularly in advanced stages of the disease the thrill and murmur often disappear, and the lesion is readily overlooked. A sharp first sound, evidence of enlargement of the right heart, sometimes a gallop rhythm, together with a small pulse should suggest stenosis, and with recovery the thrill and murmur often reappear.

Diagnosis.—A presystolic murmur is occasionally heard in conditions other than mitral stenosis.

The Flint murmur has already been referred to under aortic incompetence. In an adherent pericardium and in vegetative endocarditis of the mitral valve, a murmur of this character is sometimes found, usually of the low rumbling variety rather than of the loud and rough character. Ewart and Rutherford have recorded a case in which all the typical signs of stenosis were present and in which the autopsy showed a fibrinous polyp hanging from the auricle through the mitral orifice.

TRICUSPID REGURGITATION.—Regurgitation at this orifice is very generally admitted to occur in health, resulting from conditions, such as violent exercise, which temporarily raise the blood pressure in the pulmonary circuit. This is often spoken of as the safety-valve action, preventing the lungs from becoming unduly congested.

In the great majority of instances, tricuspid incompetence is the result of dilatation of the right ventricle, inducing relative incompetence at this orifice; in only a comparatively few cases does the lesion depend on organic changes in the valves.

Dilatation of the right ventricle is always a secondary process. It constantly occurs in old-standing mitral lesions, and as the result of obstruction in the pulmonary circuit, from emphysema or fibrosis of the lungs. In dilatation of the left ventricle, from whatever cause, the right ventricle is commonly included in the morbid process.

The valve may be affected by endocarditis, acute or chronic, or by degenerative changes. Under these circumstances the valves of the left heart are almost invariably involved by similar lesions. In malignant endocarditis, the valve is occasionally affected alone. In thirty-nine instances, Pitt found ten in which this valve was alone attacked.

Symptoms.—These are similar to those found in mitral disease, and consist in breathlessness, with evidence of obstruction in both the systemic and the portal venous systems.

Physical Signs.—A systolic bruit is sometimes heard in the lower sternal region, having its maximum intensity just to the right of the sternum about the fourth and fifth ribs, and occasionally transmitted to the right as far as the parasternal line. It is not heard at the apex, although it may be difficult to differentiate it from a coexisting mitral murmur. In some instances a difference in timbre may be noticed. Owing to a debilitated condition of the right ventricle the murmur may be absent even in well-marked cases, and again, it may disappear under the influence of rest and digitalis. The enlargement of the right ventricle causes increased pulsation in the epigastric and lower sternal regions. Dulness extends to the right border of the sternum or for two or three finger-breadths beyond, although it is frequently masked by emphysema.

Pulsation in the veins, accompanying each systole of the heart, forms important evidence of the condition under discussion. It depends on a reflux of blood in the dilated veins after their valves have become incompetent. It is seen in the external and internal jugulars, and sometimes even in more distant veins such as the brachial. Care must be taken not to confuse true venous, or, as it is sometimes termed, positive pulsation, with certain undulatory movements of these vessels. If the vein is emptied from below, positive pulsation continues.

Venous pulsation is also observed in the liver. The enlarged organ, grasped between the hands, presents a true expansile pulsation, and not merely a transmitted epigastric impulse from an enlarged right ventricle.

TRICUSPID STENOSIS.—This condition, although rare, is more frequent than are lesions at the pulmonary orifice. Pitt found it 87 times in 12,000 autopsies.

Congenital stenosis is not uncommon in still-born children, or in those who have lived a few days. It is frequently associated with other cardiac abnormalities or defects.

It has been asserted that almost all cases are of congenital origin, but this view is not borne out by statistics. In Pitt's series of 87 cases, only one patient died under ten, and in Herrick's tabulation of 40 cases the youngest patient was twelve years old, with a history of acute rheumatism two years previously, facts which strongly suggest an acquired origin. In the great majority of cases, tricuspid stenosis is associated with a similar process in the mitral, and often with disease of the aortic segments as well. In Leudet's series of 114 cases the tricuspid valve was affected alone in only one instance, and in Herrick's once in 40 cases. Females are affected about four times as often as males. A history of acute rheumatism was present in 10 or 25 per cent. of Herrick's series, chorea in 2, doubtful rheumatism in 4, no rheumatism in 9, and in 15 there was no record. In Pitt's cases, however, rheumatism played a predominant rôle in the etiology.

A fatal issue usually results in patients who are under thirty, and in only 12 cases out of 151 (Leudet's and Herrick's series) did the patient reach the age of fifty. The symptoms are those of mitral stenosis of the most pronounced form. Dyspnœa and cyanosis are often extreme, and Broadbent regards pronounced dropsy as evidence of the disease. The diagnosis has been made in a few instances during life, but in the great majority of cases it has been overlooked.

A presystolic murmur and snapping first sound heard at the ensiform cartilage or a little to the right, and fading off and again becoming marked at the mitral, has been correctly interpreted as indicating stenosis of both orifices, and in a few cases a thrill has been detected in the tricuspid region. The murmurs in the tricuspid and mitral regions have also been noted as having a different character, but the characters of the cardiac sounds are often rendered difficult of interpretation owing to rapid or irregular cardiac action. The heart is enlarged to the right as in mitral stenosis, whilst both the venous and the hepatic forms of pulsation are often present owing to associated tricuspid regurgitation.

PULMONARY ORIFICE.—Disease of the pulmonary valves is usually congenital, and is then commonly associated with other cardiac anomalies. Only a few of these cases reach adult life.

The majority of acquired cases are due to malignant endocarditis. Congenital absence of one of the cusps may lead to sclerotic processes in later years, as in aortic disease.

Acute rheumatism is not a frequent cause, being present in only seven of twenty-nine cases collected by Gerhardt.

Obstructive disease is difficult to recognize owing to the frequent occurrence of systolic murmurs in the pulmonary area from other causes. A distinct thrill, a harsh murmur, and evidence of enlargement of the right ventricle are the signs which may be found, but similar signs may be caused by the pressure of an aneurism or tumor on the trunk of the vessel.

Incompetence gives rise to a diastolic murmur in the pulmonary region, often louder during expiration, and transmitted down the left sternal border. It is not heard toward the apex or in the vessels of the neck.

Enlargement of the right ventricle is usually considerable and the apex is pushed to the left. There is an absence of the arterial phenomena of aortic disease, but Gerhardt has shown that graphic representations of the pulmonary pulsations show analogous changes. By introducing a manometer into one nostril, closing the opposite one by pressure, and directing the patient to cease breathing, he obtained a tracing showing larger excursions of the lever, and a more sudden rise and fall than is obtained either in health or in aortic incompetence.

Cyanosis, venous enlargement, and pulmonary embolism have also been noticed in disease of this orifice.

Tuberculosis is not an uncommon mode of death, and is attributed to the anæmic condition of the lungs.

Combined Valvular Lesions.—In a large proportion of cases more than one valve is affected, or there may be both incompetence and obstruction at one orifice. The general features and signs usually point to predominant disease of one valve. Aortic and mitral incompetence are often associated, whilst mitral stenosis is frequently accompanied by slight sclerosis of the aortic segments, having no clinical significance.

Prognosis of Valvular Disease.—The prognosis is based partly on an estimate of the extent and character of the valvular lesion, partly on the general health and habits of the patient.

Aortic incompetence is usually regarded as the most serious of valvular affections. The arterio-sclerotic cases, owing to the frequency with which the coronary vessels are involved, are more serious than stationary rheumatic conditions. Of the valvular affections, aortic incompetence is the one in which sudden death is most apt to occur. Favorable features are a moderate degree of cardiac enlargement, a pulse not showing the collapsing character to a high degree, a distinct second sound in the arteries of the neck, and an absence of cardiac symptoms. According to N. S. Davis the average duration of life after compensation begins to break down is 3.8 years, a period which closely corresponds to Balfour's estimate of four years.

Aortic stenosis is usually regarded as the least serious of valvular lesions. In moderate grades of the disease but little disturbance of function takes place. More serious, however, are the cases with evidence of a high degree of stenosis, as shown particularly by the pulse. Arterio-sclerosis always suggests the possibility of disease of the coronary arteries, and anginal attacks convert such a suggestion to a certainty.

Sudden death is rare, although it may occur from disease of the coronary vessels, and has also resulted from occlusion of an extremely narrowed orifice.

Mitral lesions are on the whole less serious than aortic regurgitation. Stenosis is usually regarded as a more serious affection than incompetence. Osler regards the latter as almost as serious as the former, whilst N. S. Davis reverses the opinion usually held.

In many cases in which a mitral systolic murmur is heard at the apex, this lesion shows no tendency to shorten life, and in the absence of cardiac symptoms, and of other signs of cardiac disease, its presence may be regarded with but slight apprehension. More serious are the cases in which a considerable degree of regurgitation is revealed by marked enlargement of the ventricle, but even here the patient may enjoy a long period of good health, provided that symptoms of cardiac disturbance are absent.

A cardio-pulmonary murmur is not uncommon at the apex, and is heard best or exclusively at the end of inspiration. It is frequent in pulmonary tuberculosis, and in the absence of other evidence of cardiac disease may be disregarded.

The mere loudness of a murmur is in itself no index to the severity of the lesion. Very soft murmurs are often heard in failing hearts, whilst loud rasping murmurs, although indicative of valvular damage, may be present with perfect compensation.

Mitral stenosis is not incompatible with longevity, but in most cases there is a marked shortening of life. Broadbent found the average age at death to be thirty-three years in males and thirty-eight in females, and other estimates agree closely with this. Of other influences affecting the duration of cardiac disease experience shows that children bear these lesions badly, and such cases frequently terminate fatally at or shortly after puberty. Females bear valvular disease better than males, a fact which is probably to be attributed to their less active habits and to their less frequent indulgence in alcoholic excess. An exception to this rule is sometimes seen as the result of pregnancy, in which the increased strain occasionally results in serious and even fatal cardiac failure. Laborious occupations are unfavorable, as are also sexual and alcoholic excess, and the free use of tobacco.

Finally poor general health, anæmia, recurring attacks of bronchitis, hepatic and renal engorgement, and pulmonary embolism are all unfavorable signs.

Recurring attacks of rheumatism often exert a most unfavorable influence owing to fresh attacks of endocarditis, and in children rheumatic inflammations occasionally progress to a fatal issue within a few weeks or months.

Acute disease, particularly pneumonia, is often ill borne, and if survived is sometimes followed by loss of compensation. I have known several cases of mitral stenosis date their symptoms from an attack of pneumonia.

Finally, poor general health, anæmia, hepatic or renal engorgement, and pulmonary embolism are all unfavorable symptoms.

Treatment.—During the period of compensation no very active treatment should be directed toward the heart.

It is important in this stage to keep the general health up to the best possible point. For this purpose the diet should be plain and nourishing, and the coarser vegetables should be avoided as tending toward flatulence. Alcohol is unnecessary in young people, and if used at all should be taken in strict moderation with food. Tobacco is injurious, whilst tea and coffee must be avoided should they cause any cardiac palpitation or uneasiness.

In rheumatic cases special care should be taken to see that the patient is suitably clad, and even with slight rheumatic manifestations he should be confined to bed or the house.

Exercise and athletics are beneficial provided they cause no undue fatigue or are not pushed to the point of inducing dyspnœa. The more violent forms of exercise such as football or even tennis should be forbidden, but golf, mild bicycling, or rowing and walking are safer, inasmuch as they throw much less strain on the heart. In cases in which for any reason it is judged unwise to allow even easy exercise, rest in the open air is beneficial.

Medicinally, an occasional aperient; tonic doses of iron or arsenic, particularly when anæmia is present, or strychnine are valuable. Small doses of digitalis (♏ v. to x.) may be administered should any tendency to dyspnœa or palpitation exist, and the use of this drug is sometimes continued for lengthened periods with decided benefit.

When compensation begins to fail, and dyspnœa, dropsy, and palpitation become marked, a more active plan of treatment is required.

In most instances of uncomplicated valve lesions failure of compensation is due to dilatation, brought about for the most part by excessive muscular work, although in some cases it is induced by severe mental strain. The first object is therefore to secure physical and sometimes mental rest. When the symptoms are at all severe, absolute rest in bed must be enjoined; and treatment by this method alone is sometimes sufficient to relieve dyspnœa and remove dropsy. It is, however, advisable in most instances to use medicinal or other agents, which hasten recovery and alleviate distress.

Of the cardiac stimulants by far the most valuable is digitalis. This remedy slows and strengthens the muscular contraction of the heart, whilst the pulse rate is reduced and becomes more regular, the peripheral arteries are contracted, the renal arteries relax, and a large volume of blood passes through the kidneys as shown by the free diuresis.

In aortic incompetence the objection to digitalis is sometimes raised that it prolongs diastole and hence allows of freer regurgitation. This objection is largely theoretical, and many cases receive a marked degree of benefit from the increased muscular action, dyspnœa is relieved, and in favorable cases compensation is completely restored. It is in mitral disease, particularly when dropsy and dyspnœa are present, that digitalis induces the most brilliant results. Dyspnœa is relieved, free diuresis is set up, and dropsy lessens and disappears.

In mitral incompetence, not only is the muscle stimulated, but the regurgitation is lessened owing to the more perfect closure of the auriculo-ventricular ring. In stenosis the lengthened diastolic period allows more time for blood to pass from the engorged auricle through the narrowed valve.

The action of digitalis is somewhat slow and it is not until the third day that the full effects of the drug are seen. When marked slowing of the pulse to 60 or under, or a fall in the quantity of urine occurs, the dose should be lessened or stopped, owing to the danger of toxic manifestations, which reveal themselves in the form of nausea and vomiting, weakness and irregularity of the pulse, or a double beat of the heart to one of the pulse.

The drug should be given freely for from forty-eight to seventy-two hours when the symptoms are at all urgent—say in doses of ♏ xv. of the tincture or ʒ iv. of the infusion every three or four hours. Smaller doses are usually sufficient (♏ x.–xv. t.i.d.) in the absence of severe symptoms. Nausea and vomiting are sometimes produced by even moderate doses, and in such cases rectal administration of one or more large doses of the fluid extract are often extremely beneficial. Five or ten minims (♏ i.–gr. i. digitalis) administered with starch in this way often act rapidly, and I have seen the pulse slowed and dyspnœa relieved in the course of a few hours. An old and reliable preparation is Guy's pill, consisting of gr. i. each of digitalis, squills, and pil. hydrarg.

Strophanthus is a valuable substitute for digitalis. It acts on the heart like digitalis, but has not the same tonic effects on the arteries. It is consequently sometimes preferred in arterio-sclerotic cases with increased arterial tension. It is inferior to digitalis in removing dropsy, but is sometimes of value in alleviating cardiac symptoms when this drug fails. Sparteine acts in a similar manner to strophanthus, but as a rule is inferior to it.

Caffeine is occasionally useful as a substitute for digitalis. It sometimes induces restlessness and insomnia.

Suprarenal extract has recently come into use as a cardiac tonic; it acts on the muscular substance of the heart. Some of the clinical reports are very encouraging and it seems worthy of further trial.

Strychnine is a valuable adjunct to digitalis and may be administered in doses of gr. $\frac{1}{80}$ three to six times daily.

Diffusible stimulants such as alcohol, ether, and ammonia are of value in emergencies, and until the more slowly acting stimulants affect the heart.

A dose of calomel, gr. v. with gr. x. of bicarbonate of soda, is often administered with benefit preceding the course of digitalis. It relieves portal congestion and engorgement of the right heart, and increases the efficacy of digitalis.

In arterio-sclerotic cases the long-continued administration of iodides often proves of much value in controlling palpitation and other symptoms, possibly by lowering peripheral resistance. Nitroglycerin is also a valuable agent in lessening peripheral resistance and is often advantageously given with digitalis in doses of ♏ i. of the one-per-cent. solution.

Obstinate or persistent symptoms often require special measures for their mitigation or relief.

Dyspnœa continuing after the use of digitalis, and especially when nocturnal in character, is usually relieved in a remarkable manner by a hypodermic injection of morphine, and in advanced cases this drug is invaluable.

Sleeplessness sometimes yields to paraldehyde, trional, or sulphonal, but, as it is often dependent on dyspnœa, these remedies are much inferior to morphine.

Pain over the cardiac region is often alleviated by the iodides, especially in arterial cases, or by nitroglycerin.

DROPSY.—Dropsy may be diminished by free purgation. For this purpose calomel, salines, and hydragogues, especially compound jalap powder, are most serviceable.

Needle puncture of the distended limb with strict aseptic precautions allows considerable quantities of the fluid to drain away. Southey's tubes are also very efficacious, but there is considerable danger of inflammatory changes taking place in the subcutaneous tissues.

Theobromine in doses of gr. lx. to gr. xc. daily may be used with occasional benefit as a diuretic when the urinary secretion is persistently small.

When considerable quantities of fluid collect in the abdominal or the pleural cavity paracentesis is necessary and may be repeated as often as required.

Palpitation is much relieved by an ice-bag over the precordial region. A diffusible stimulant, or strychnine in full doses often proves of signal service. If the attack is severe, a hypodermic injection of morphine may be given. Strict attention to diet together with quiet and rest is also essential.

Vomiting.—Food must sometimes be withheld for some hours, or replaced by sips of hot water, brandy, or champagne. After the vomiting has yielded or lessened, liquid food may be cautiously tried. Milk may be given freely diluted with lime water, Vichy or effervescing waters, or peptonized beef essences are often tolerated when other foods are rejected. In obstinate cases rectal alimentation may become requisite. The frequent action of digitalis in inducing vomiting must be remembered in this connection. It must often be withheld for a period, but should not be given up without good reason.

Venesection is occasionally required when marked cyanosis or dyspnœa is present, and ten, twenty, or even thirty ounces of blood may be abstracted from the arm. A valuable measure which has largely fallen into disuse is the application of a few leeches to the precordial region followed by hot fomentations to encourage bleeding.

During the past few years much has been written on the Nauheim methods, consisting in bathing in aerated water, and movements with resistance. The baths lessen the peripheral resistance, and the movements tend to empty the veins. Percussion and skiagraphs show a lessening of cardiac dilatation after application of these methods. They seem to be more successful at the natural springs than when applied in hospitals or other localities. *Frederick G. Finley.*

HEART, RUPTURES OF.—These are divided into two classes: *First,* Those due to degeneration of the myocardium, the so-called spontaneous ruptures; and *second,* those due to traumatism.

Instances of the first class, while not frequent, are more often observed than are those of traumatic origin.

MORBID ANATOMY.—Spontaneous rupture of the heart generally occurs in the substance of the left ventricle owing to the greater frequency of degenerative changes in this locality, and to the greater strain which this part of the heart has to bear in lifting the blood through the systemic circulation.

The anterior face of the ventricular wall somewhat above the apex is usually the site of the tear. Although it is said that the tear usually begins from within and proceeds to the outer face, the reverse may happen, and it is impossible to tell from inspection upon which surface the lesion originated. The sites of the rupture in 55 cases collected by Elleaume were as follows: 43 in the left ventricle, 7 in the right, 3 in the right auricle, and 2 in the left auricle.

The tear may be complete or incomplete, and may vary in extent from a centimetre to the length of the ventricle. It is usually single, but as many as five have been noted, sometimes intercommunicating. The rent is generally ragged, irregular, and sometimes ecchymosed at the edges. Its course through the ventricular wall may be tortuous so that the endocardial and epicardial openings do not correspond. Usually the fissure runs parallel to the course of the muscular fibres. Those ruptures which are due to an abscess of the heart wall or to hemorrhagic softening more frequently are in the form of an ulceration or perforation. The immediate result of this accident is the distention of the pericardial sac with blood which generally forms clots, leaving the serum in the pericardium.

Cases have been noted in which a plug of fibrin has more or less completely occluded the tear in the heart wall.

ETIOLOGY.—This form of rupture is always the result of disease of the myocardium, softening, fatty degeneration, fatty infiltration, etc., dependent generally upon occlusion or fibrosis of the coronary arteries. This degeneration may be local or general, and may result primarily in an aneurism of the heart or aorta, which may burst. Very rarely we have abscess of the heart wall, which bursts and leads to rupture. The *exciting* cause of the lesion may be a sudden and perhaps an unusual motion like stumbling or falling, lifting or straining. A comparatively frequent cause is running for a train. Anger, excitement, and mental or physical shock may determine the accident. Not infrequently it occurs while the patient is in perfect rest. He may be asleep in bed. The male sex is considerably more liable to this accident than the female. It seldom occurs before the fiftieth year, more often after the sixtieth.

SYMPTOMS.—Seldom are the premonitory signs of this disaster distinctive. There would naturally be signs of a diseased and feeble heart. Comparatively few diseased hearts, however, go on to rupture. On the occurrence of the lesion, death is usually instantaneous; the patient not infrequently being found dead in bed with the clothes not even disturbed. In case the rupture is oblique in direction and small in extent, the patient may survive several hours, or even days.

Dr. Langman has recently reported a case of a man who had two ruptures of the heart wall, one having happened two weeks before the other. He died four hours after the occurrence of the second, which was in the left ventricle, the first was in the right. The heart walls were thin, but not fatty.

The special symptoms denoting approaching dissolution are intense precordial pain, restlessness, dyspnœa, rapid, feeble, and fluttering pulse; vomiting, cyanosis, loss of consciousness, and convulsions.

Hampeln has observed that there is greater pain in rupture of the pericardial portion of the aorta than in that of the heart substance proper.

The physical signs, even when the patient's life is sufficiently prolonged, are more or less indefinite. The pulse is weak and intermittent. The heart sounds are muffled, distant, and imperfectly developed, with probably some increase of pericardial dulness.

DIAGNOSIS.—This is so uncertain that it cannot as a rule be relied upon, although in some cases the condition has been made out ante mortem. A diagnosis ought certainly to be made in those cases in which, in addition to the rational symptoms already detailed, percussion affords evidence that the pericardial area has recently undergone enlargement.

PROGNOSIS.—This is uniformly unfavorable; no case of spontaneous heart rupture having ever been known to recover, although life may be prolonged for several days and even weeks, by judicious treatment and nursing.

TREATMENT.—This is mainly palliative and can have no effect on the diseased condition of the heart. Cold applications, morphine hypodermatically, a strict maintenance of the recumbent posture, perfect quiet, and warmth to the extremities may prolong life for a limited period. Stimulants are contraindicated.

Traumatic Ruptures of the Heart are quite rare. This organ from its shape and position, its mobility and the protection afforded it by the elasticity of its walls, and by its overlying and surrounding structures, is seldom ruptured—except in cases in which the entire chest wall is crushed in. A certain number of cases of rupture of the heart walls have occurred with comparatively little injury to the chest wall, even without penetration of the pericardial sac. The writer was able, in 1899, to collect forty-five cases of heart rupture, not due to stab or gunshot wounds, and generally speaking caused by an injury from the effects of which the heart walls would be expected to escape scot free. In the majority of the cases there was evidence of disease or abnormality of the organ. But in a few cases the heart muscle was healthy.

The writer reported the case of a vigorous man of twenty-eight who was riding his bicycle rapidly, when the forward wheel struck a hose pipe which was filled with water and which lay across the road. As a result of this sudden strain the bicycle broke at the "head," and the rider was thrown to the ground with great violence, the detached handle-bar post interposing itself between his body and the hard road. This impact fractured the sixth costal cartilage somewhat to the left of the sternum and drove the distal end attached to the rib into the pericardial sac. The sac did not tear; but the force of the blow was so great that the right auricle was torn entirely through. A triangular flap (see accompanying photograph, Fig. 2596) of the heart wall had been lifted up, and when it was turned back the ventricular cavity was exposed. The heart weighed eleven and one-quarter ounces, and its valves and muscular substance were healthy and competent. The man lived for an hour and a half after the accident and partly recovered from shock. The cause of death was apparently the distention of the pericardium with blood, of which from eight to ten ounces, mostly coagulated, was found in the sac.

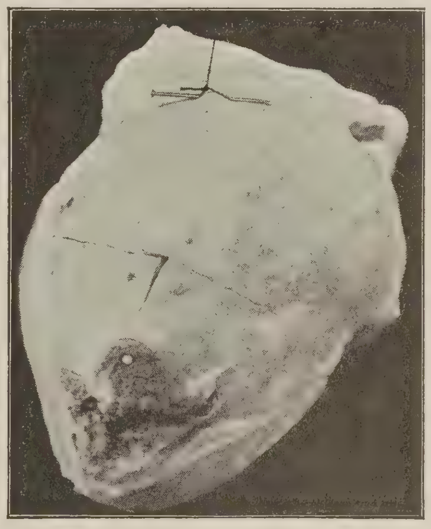

FIG. 2596.—Showing Traumatic Rupture of Heart at Apex of Right Ventricle.

Of traumatic ruptures a majority occur in the right ventricle near its apex. Of Gamgee's 28 cases, in 9 there was no fracture of ribs or sternum and either no bruise of the parietes or a very slight one. The pericardium was intact in at least one-half of the cases, and in 22 in which the principal seat of the injury was noted, the right ventricle was torn in 8; the left in 3. The left auricle was injured in 7 and the right in 4. The apex of the right ventricle is a favorite spot for traumatic rupture, first, on account of its exposed position as it comes in contact with the chest wall in systole, and second, because the myocardium is thinnest at this point. Ruptures of the muscular fibres most frequently occur in systole when they are tense and firm and offer the greatest resistance to the impact of the opposing force. If struck in diastole when the ventricles are filled with blood, their walls being flaccid, the seat of rupture will be in the resisting valves, or on the interventricular septum.

So far as ascertained the longest time that a person has survived after traumatic heart rupture is seventeen hours. The symptoms of intense pericardial pain, weak, fluttering or intermittent pulse, dyspnœa, lividity, cold extremities, sweating, and convulsions, are much the same as in cases of spontaneous rupture. With the history of a blow upon the chest, especially if the ribs or their cartilages are found fractured, the diagnosis of heart rupture might be made out and bold surgery might save a life. The technique of the operation would be the same as that laid down for wounds of the heart substance. No other treatment could be anything more than palliative.

Richard Cole Newton.

HEART STRAIN.—This may be defined as the untoward effects of overexertion on the previously normal heart.

While the metabolic changes during violent exercise doubtless produce toxins—"fatigue products"—affecting the nutrition of the heart, and causing relaxation of its tonus, the effects are largely mechanical. The heart is called upon to do more work than when at rest, to receive and send out more blood, and to do this under different conditions of blood pressure and nutrition.

The work done by the heart in a given interval of time depends on two factors—the amount of blood sent out and the resistance against which it is pumped. The heart's arterial output in turn is dependent upon its venous input,—that is, the heart normally sends out the same amount of blood per second as it receives. The resistance or aortic blood pressure depends on the balance between the output of the heart and that of the arteries—the heart endeavors to overcome the peripheral resistance. The output of the heart remaining the same, in other words, the resistance would depend upon the state of contraction or dilatation of the arterioles.

The peripheral blood pressure shows, during active exercise, a temporary increase, which is followed, even if the exercise continues, by a very marked decrease. In a recent examination of the contestants in a twenty-five-mile running race with which the writer was associated, this fall was invariably present in men examined at the finish and was shown by direct study of the blood pressure and by the sphygmograph. The temporary rise is due to increased output of the heart. The pressure of the muscles of the extremities on the large veins, the similar action of the muscles of the abdomen and diaphragm on the portal system, and the increased activity of the respiratory apparatus, all favor the flow of blood to the right auricle, and through the lungs to the left heart. For a while the increased output causes an increase in arterial tension and increased work for the left ventricle, but there is soon a dilatation of the peripheral vessels, especially in the muscles, and a consequent fall of pressure with relief to the left heart. According to Allbutt, when this adjustment is accomplished the phenomenon of "second wind" occurs.

Training.—When the heart is frequently called upon to do a large amount of work changes take place through which it is able to meet larger demands upon it. In trained athletes, especially in those engaged in sports requiring long-continued violent exertion, as in long-distance runners or oarsmen, the heart area shows marked and progressive enlargement. Inspection frequently shows visible bulging of the left chest and percussion shows more or less enlargement. The left border may be outside the nipple, and the right correspondingly changed. The impulse is often diffuse and powerful.

The explanation of these findings is doubtless that the heart muscle undergoes hypertrophy exactly like any other muscle. Perhaps there is some dilatation as well, the capacity of the organ as well as its strength being increased. The respiratory apparatus also becomes more efficient, but the changes here are less easily determined than in the heart. It cannot be too strongly insisted upon that these changes are physiological. More than that, it is probable that without more or less cardiac hypertrophy a man cannot with impunity engage in violent athletic contests, while with the heart properly trained he will rarely do himself any immediate damage.

What are the remote results of normal training? Are these hearts more subject in after years to functional disorders or degenerative conditions than others? Important as this question is in connection with modern college athletics there is much doubt about its answer. It is probable that a heart in which simple hypertrophy has occurred as a result of training, which has never suffered from any of the acute or chronic disorders presently to be described, which has, in short, enabled its owner to perform tasks beyond the power of other men without at any time causing any untoward symptoms—such a heart will, after the cessation of training, return quietly to its original size. The decrease is, however, slow. Darling found that after a year the Harvard rowers still had large hearts. But, as Darling remarks, hypertrophy of the heart from training is no more undesirable and gives the patient no more trouble than the corresponding hypertrophy of the biceps. Perhaps the most thorough investigation of this matter was that of Morgan (1873) who studied the after health of the 294 men who rowed in the Oxford-Cambridge races between 1829 and 1869. But seventeen claimed to have been injured, and in only two or three would the evidence convince us to-day that previously healthy men suffered permanent damage to the heart. The mortality was less than comparison with insurance statistics would lead one to expect, and Morgan concluded that in the majority of cases training does great and lasting good. On the other hand Stengel mentions cases in which trained men several years after the cessation of active athletics, with no intervening symptoms, began to complain of sensations of oppression and distention in the chest with "consciousness of the heart." Certainly, if in the course of training the heart has suffered any of the forms of strain, permanent damage may remain. Too little attention has been given the subject of training by medical men and the matter cannot be said to rest at present on very firm scientific foundations.

Acute Heart Strain; Acute Dilatation.—When the heart is examined immediately after an athletic contest it is common to find enlargement of the area of dulness over and above what was already present as a result of training. So commonly is this the case, and so rapidly does the temporary enlargement subside that some dilatation or relaxation would seem to be physiological after sufficient severe exercise.

Under constant conditions of intraventricular blood pressure the total stress on the walls of the ventricle varies with the size of the cavity, and the increase in total stress is as the cube of the radius of curvature, assuming that the ventricle is approximately spherical. It is evident that as dilatation advances the heart muscle has to bear a constantly increasing strain, and that should it continue a point would be reached where it could no longer contract at all (paralysis from overdistention.)

There are, however, certain things which limit this process: in the first place, up to a certain point the muscle fibres act to better advantage when stretched than when partly contracted; secondly, the chordæ tendineæ and trabeculæ tend to prevent excessive stretching; thirdly, the fall of blood pressure as exercise continues relieves the strain; finally, the auriculo-ventricular orifices share the dilatation, or the mitral and tricuspid sphincters relax and regurgitation occurs. In regard to this last point, the normal mitral and tricuspid valves are able to close an orifice considerably dilated, and the action of the so-called sphincters is not fully admitted by physiologists. According to Albutt sudden stress affects chiefly the aortic area, prolonged exertion the right heart.

Acute dilatation may result from severe exertion in any form, though it is said to be most frequent when the legs are used, as in running, rowing, forced marching, bicycling, and mountain climbing. It has resulted from fright and other emotional shocks, and from sudden peripheral vaso-motor contraction the result of cold bathing. It is much more apt to occur in untrained individuals, but even in the Harvard University crews each race is followed by temporary increase in the area of dulness. It is more easily produced in older persons, in those with beginning degenerative conditions, and after convalescence from acute diseases.

The symptoms due to severe physical exertion are familiar to every one—rapid pulse, pallor, and dyspnœa. In extreme cases these symptoms are severe and the skin is cyanosed or grayish. There may be a sense of severe oppression in the chest, dizziness, nausea, or nosebleed. The man may fall to the ground unconscious or even dead. But recovery is generally prompt, so that the athlete who falls exhausted at the finish of a hard-fought race may be well in an hour and ready to win another event.

But symptoms may persist for some days or weeks, during which there are dyspnœa on slight exertion, palpitations, præcordial oppression, pain or "side-ache," with vertigo, and albuminuria. The heart is rapid and irregular. Exacerbations of these symptoms may occur after a meal, without exciting cause or may even waken the patient at night. The patient may die in a few days, compensation not being established. Sometimes there is permanent damage and he remains "broken-winded" to the end of his days—unable to perform any unusual exertion without dyspnœa and cardiac irregularity.

The most important physical sign of pathological dilatation is sudden and persistent increase in the area of cardiac dulness. It must be remembered that the heart of the athlete is generally already enlarged from hypertrophy and that some further temporary dilatation is so common that it cannot alone constitute a disease. The impulse is often feeble and the rhythm irregular. There may be a murmur, usually systolic, at the base to the left of the sternum. The murmur is fugitive, generally disappearing within a few minutes. Its nature and position of maximum intensity are somewhat variable.

The explanation of this murmur which is frequently present in the normal cases of slight temporary dilatation is a question that has excited considerable discussion. Stengel believes that it is due to dilatation of the pulmonary conus arteriosus. In a study of the runners in the Boston Athletic Association's Marathon race (twenty-five miles) of 1899, Williams and Arnold found fugitive systolic murmurs at the base to the left of the sternum in eleven out of thirteen cases examined. In some it was transmitted along the left border of the heart to the apex and in some to the back. They consider that the heart shared in the general muscular exhaustion, and that the mitral sphincter and papillary muscles relaxed, giving a true regurgitation into the auricle. Darling found similar murmurs in the Harvard crew after racing and accepts Williams' and Arnold's explanation, which appears to be widely adopted.

The writer has assisted in examining the hearts of the Boston Marathon runners for the past two years, during which murmurs were not found with the same regularity as by Williams and Arnold. Some might be described as mere "murmurishness" of the first sound. In two cases murmurs were found at the right of the sternum. In some they were present both before and after the race, and in one or two they were present at the start and not at the finish. If any considerable mitral regurgitation had occurred, evidences of pulmonic engorgement would be expected. These were not present, nor were they reported by either of the other writers mentioned. Possibly some murmurs were cardio-respiratory, and certainly some—those that were present at the start only—were due to nervousness. Such murmurs from nervous excitement are matters of common observation. Further study of the matter is needed.

The diagnosis of acute dilatation is generally obvious. The enlargement and murmur which are the normal result of severe exertion will soon disappear, while in the serious dilatation they, together with the symptoms, will be more persistent. Persistence of the murmur with the other signs of mitral insufficiency after the disappearance of the symptoms will usually mean a pre-existing valvular lesion. If the heart is known to have been previously normal a permanent murmur with pain, œdema, and gradual recovery with hypertrophy may indicate a ruptured valve.

Treatment should be directed to relieving the heart from work as much as possible. Rest in bed is imperative in the severe cases. When cyanosis is extreme and the right heart distended, venesection may be called for, more often in older full-blooded men than in young athletes. For drugs, strychnine and alcohol may be used, with digitalis if the pulse is weak and rapid. The latter should be used cautiously especially in the early days; later it may be of the greatest value. During and after convalescence the patient must be very careful not to overexert himself. An athlete should return to active exercise, if at all, very gradually and under close medical supervision.

In prophylaxis the most important point is training, the object being to produce a hypertrophy of the heart comparable to the accompanying development of the peripheral muscles. This is illustrated by the cases of Williams and Arnold. The only two of their thirteen who failed to show enlargement dropped out of the race before reaching the finish. The avoidance of alcohol, tobacco, and other excesses is important.

The question as to what findings should exclude a man from participation in a race or game is difficult to answer. We are not justified in excluding a man because his heart does not show the requisite hypertrophy. If he has been under constant supervision there is no difficulty—persistent murmurs with dyspnœa and irregularity after preliminary trials should exclude him. But a murmur just before the start is of no significance.

Rupture of a Valve is a rare result of overexertion in the normal organ. The aortic and mitral valves are most frequently involved. There is generally severe pain at the time of the accident, often with a sense of something giving way in the chest. The usual signs of regurgitation are present. Immediate death may occur or recovery, according to the severity of the lesion.

Rupture of the Heart is even more rare and probably never occurs in the normal organ. A number of cases have occurred in degenerative conditions as a result of sudden strain. Death is usually instantaneous.

CHRONIC HEART STRAIN.—By this is meant those forms of cardiac disturbance which result from frequently repeated exertion—the functional condition known as "irritable heart" and the hypertrophied or dilated organ with symptoms of overaction. The pathology of these conditions and their relation to one another are obscure. J. M. Da Costa, who studied soldiers in the War of the Rebellion, considered that irritable heart was an early stage whose continuance resulted in hypertrophy and overaction. Treadwell studied the same class of men seven years after the war and concluded that the symptoms were due to dilatation when compensatory hypertrophy had failed.

While repeated overexertion is the chief element in the production of many of these cases it is certain that, especially in the functional cases, syphilis, and excesses of alcohol, tobacco, tea and coffee, play an important part. They often commence after convalescence from acute diseases—diarrhœa, digestive troubles, typhoid, or malaria. Improper food, insufficient sleep, and exposure or sexual excesses are occasional factors. In athletes worry over an approaching contest and in soldiers the excitement of an active campaign may have a direct or indirect influence. Constriction of the chest by heavy and improperly adjusted accoutrements has been given a prominent place.

Most of the "soldier's hearts" occur in men under twenty-five, of tall, lanky build. In civil life it is commoner in pedestrians, mountain climbers, and bicyclists. It may result from excessive dancing. J. Burney Yeo describes similar conditions in girls at puberty as a result of rapid growth and educational strains. In college athletes who are kept in the best physical condition and whose training is carefully managed it is apparently uncommon. Still, the cause of "staleness" or overtraining is very obscure and probably the heart (Darling) is a factor.

The symptoms and course of "soldier's heart" are thus summarized by Da Costa: "A man who had been for some months or longer in active service would be seized with diarrhœa, annoying, yet not enough to keep him out of the field; or, attacked with diarrhœa or fever, he rejoined his command and again underwent the exertions of a soldier's life. He soon noticed that he could not bear them as formerly; he got out of breath, could not keep up with his comrades, was annoyed with dizziness and palpitations; his accoutrements oppressed him, and all this though he appeared well and healthy. Seeking advice from the surgeon of the regiment, it was decided that he was unfit for duty and he was sent to the hospital, where his persistently quick-acting heart confirmed his story, though he looked like a man in sound condition. Any digestive disturbances which might have existed gradually passed away, but the irritability of the heart remained, and only very slowly did the excited organ return to its natural condition. Or it failed to do so, notwithstanding the use of remedies which control the circulation: thus the case might go on for a long time, and the patient, after having been the round of the hospitals, would be discharged, or, as unfit for active service, be placed in the Invalid Corps."

The important symptoms are precordial pain, usually paroxysmal; palpitations, tachycardia, the heart being characteristically more rapid in the upright position or after slight exertion; dyspnœa; and nervous disturbances—headache, dizziness, and sleeplessness. The symptoms may be absent except during exercise or they may come on paroxysmally during rest or sleep.

Examination in the functional cases shows little or no enlargement, the chief physical signs being irregularity or rapidity of action on slight exertion or on suddenly assuming the erect posture. Systolic murmurs may be present, but they are inconstant and variable. The first sound is described as short and valvular. In the cases with permanent dilatation the area is large, the impulse labored and diffuse, the first sound dull and prolonged. Constant murmurs may be present; due to regurgitation from relatively insufficient valves.

In the differential diagnosis it must be remembered that a true valvular lesion from endocarditis may exist without causing a murmur, especially in the case of mitral stenosis, and that the patient with such a lesion may correctly date the onset of symptoms to a period of over-exercise. Renal, pulmonary, and vascular degenerations must be borne in mind. Some of the cases are clinically identical with myocarditis.

The prognosis is uncertain. Complete recovery may occur, but as a rule more or less irritability remains. The quotation from Da Costa given above indicates what seems to be the common result in military cases. It is probable that many cases become virtually ones of valvular disease—relative insufficiency—or of myocarditis. Some go from bad to worse and die within a few years.

For prophylactic treatment training is again of great importance, or at least occupations requiring severe exertion should be entered into gradually so that hypertrophy of the heart muscle may occur before the full strain is put on the organ. Active exercise should be resumed with great care after recovery from acute disease. Excesses, especially of tobacco and alcohol, should be avoided permanently by those whose occupations call for a large amount of work on the part of the heart.

When the condition of irritable or dilated heart is once established prolonged rest is imperative with gradual return to active life after recovery. Among drugs digitalis will be of greatest use. The bromides will also be of service. Iron and other tonics may be called for.

In conclusion the statement must be reiterated that the danger from over-exercise in healthy hearts is not great, especially if the subject be well-trained. Indeed, Darling mentions one oarsman in whom, at the beginning of the season, the heart showed obvious signs of mitral regurgitation from previous organic disease of the valve. As the season advanced the symptoms and signs entirely disappeared, and the man did valuable work in the final hard-fought intercollegiate boat race. Such instances may be rare, but the heart certainly has a vast reserve power.

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HEART, THROMBOSIS OF.—The blood clots found within the heart cavities may be divided into three classes: *post-mortem clots, ante-mortem* or *agonal clots,* and *true thrombi.* The post-mortem clot is formed after the heart has ceased to beat; it is a soft, dark-red, jelly clot filling up the cavity of the auricle or ventricle and not adherent to the heart wall. It is commonly known as cruor or the currant-jelly clot. Such coagula are found usually in the right auricle and ventricle, but may be present in all four of the cavities. When coagulation occurs rapidly after death the clot is uniformly red throughout; but if coagulation is delayed the uppermost portion of the clot may be light-colored or yellowish from the sinking of the red cells. In themselves the post-mortem clots are of significance only in so far as the character of the blood and its coagulability are concerned. If coagulation takes place while the ventricles are contracted in rigor mortis the clots will be found in the auricles only, but, if coagulation be delayed until the contraction of the ventricles has passed, the ventricular cavities may again become filled with blood which later coagulates.

The ante-mortem or agonal clot is a white or mixed clot found in the periphery of the large veins, right and left auricles, and right ventricle, but rarely in the left ventricle. Such clots consist of fibrin with few or many leucocytes, while that part of the clot toward the axial stream may contain red blood cells. They develop during the slowing of the blood stream in cases of slow death, and are formed only in the peripheral stream where there are no red cells. As the current becomes slower red cells are caught in that portion of the clot toward the central stream. As soon as death occurs and the current comes to a standstill, the blood in the central stream coagulates forming a post-mortem currant-jelly clot. Combinations of agonal and post-mortem clots are thus formed and are distinguished by the presence of a central red clot surrounded by a peripheral layer of white clot. The agonal clot is soft, but much firmer than the currant-jelly clot. It is not attached to the endocardium and is easily removed from between the trabeculæ of the ventricular wall. It is further distinguished from true cardiac thrombi in its moistness, translucency, and greater elasticity. On microscopical examination the agonal clot is found to consist almost entirely of a coarse reticulum of fibrin; on the other hand the fibrin in the post-mortem jelly clot is in the form of fine fibrillæ. The significance of the agonal clot is only that of a slowly progressive heart failure; in cases of sudden death without previous impairment of cardiac efficiency the white peripheral clots are either very small or absent, while in cases of slow death in chronic valvular disease, cachexias, etc., they may be very large. Care should be taken to differentiate between these and the true heart thrombi for which they are frequently mistaken.

The true heart thrombi are yellowish, reddish, or reddish-gray or brown, opaque, dry, inelastic, brittle, and in the great majority of cases more or less adherent to the endocardium. The conditions under which they are formed are practically the same as those of thrombosis of the blood-vessels, the chief factors being lesions of the endocardium, disturbances of the circulation, and changes in the chemical composition of the blood. Of these the endocardial changes are by far the most important. At the point of lesion blood plates are first deposited, followed by the processes of conglutination and coagulation as in the formation of thrombi in the vessels. The resulting thrombus is usually a mixed clot, very frequently laminated. When formed in the peripheral stream with rapid circulation it may be entirely white; if the current is very much slowed it may be red throughout. In old red thrombi the diffusion of the hæmoglobin from the red cells may give a washed-out reddish or brown color. The latter color is also the result of the formation of blood pigment from the disintegration of the red cells. The surface of the thrombus is not infrequently ribbed; this appearance has been explained as being due to wave-like movements in the blood, the process being analogous to the formation of wave marks on sandy bottoms. The general external appearances of cardiac thrombi are dependent upon the manner of formation, rapidity of development, and the local conditions of the circulation. The size and shape of cardiac thrombi show great variation. They may be so small as to be hidden between the muscle columns, or so large as completely to fill one of the heart cavities. They may appear as small globular masses projecting from between the muscle trabeculæ (globular vegetations); or as flat, circumscribed masses firmly attached to the heart wall. On the valves they may form bead-like excrescences or vegetations. Not infrequently the thrombus is attached to the endocardium by a pedicle (heart polyp); as the result of the tearing of such attachment free globular thrombi may be formed (ball thrombi). In rare cases the thrombus may be spread over the endocardium like a false membrane.

The thrombus when cut into may be found to be made up of dry and brittle laminations, in some instances the central portion of the thrombus is under slight pressure easily crumbled to dust. In other cases the central portion may be cystic, the cavity filled with a thick reddish-brown or pus-like substance. Such secondary degenerations are of frequent occurrence. The most common is a simple softening or liquefaction; when many leucocytes are present a grayish pus-like fluid may be formed; if the degenerating portion is made up of red cells alone a grumous reddish-brown fluid results. Calcification of the thrombus may also take place, resulting in the formation of a cardiolith. As a more favorable sequela of cardiac thrombosis organization of the thrombus may occur, the latter becoming ultimately converted into a nodular or diffuse fibrous thickening of the endocardium. In some cases both the degenerating and the organized thrombi have been mistaken for cardiac neoplasms, cysts, and fibroma respectively. It is also not improbable that some of the growths on the endocardial surface described as myxoma were recently organized thrombi.

The microscopical examination shows the cardiac thrombi to be composed of fibrin, disintegrated blood cells, blood pigment, masses of calcification, etc. In case of simple softening of the central portion the cavity thus formed contains granular débris, blood pigment, etc. In recent thrombi the leucocytes present may still show traces of their nuclei. If organization has begun fibroblasts and new capillaries may be seen extending from the endocardium into the thrombus.

Thrombi are more frequently found in the right side of the heart than in the left. In the auricles the appendix, and in the ventricles the neighborhood of the apex are the favorite seats of location. The pedunculated thrombi (cardiac polyps) are of frequent occurrence in the right ventricle, while the free ball thrombi, in the majority of recorded cases, were found in the dilated left auricle in cases of mitral stenosis. Cardiac thrombi may be single or multiple, and may be found at any age. According to their location in the heart they are also designated as parietal and valvular.

Etiology.—The changes in the endocardium leading to thrombosis are either inflammatory, or degenerative, or necrotic in nature. These lesions may be the result of the local action of pathogenic bacteria or due to general intoxications, disturbances of nutrition, changes in the blood, etc. The pus-forming organisms, gonococcus, and tubercle bacillus have been found in cardiac thrombi under such conditions as to make it very probable that they were the exciting factors of the thrombosis. The valvular vegetations are in the majority of cases due to bacteria. In the acute infections fatty degeneration of the endocardial endothelium not infrequently leads to thrombosis. Local changes in the myocardium, such as anæmic infarction, myocarditis, etc., are usually associated with the formation of thrombi on the overlying endocardium. Aneurismal dilatations of the cardiac wall are very likely to be partly or wholly filled by a thrombus. In many chronic diseases in which there are general disturbances of nutrition, systemic intoxication, etc., as in chronic nephritis, pulmonary tuberculosis, chronic valvular disease, etc., heart thrombi are frequently found. In pulmonary tuberculosis they are of such frequent occurrence as to give rise to the suspicion that in many cases they may be due to the local action of tubercle bacilli which have lodged upon the endocardium. Cardiac thrombosis often occurs in cases of general cachexia (marasmic thrombi). In severe superficial burns of the skin the changes produced in the blood may lead to the formation of thrombi, both in the right side of the heart and in the pulmonary arteries. Small emboli coming from venous thrombi and lodging upon the valves or between the muscle trabeculæ of the right ventricle may give rise to secondary or induced thrombi. Sclerotic changes in the valves or mural endocardium followed by atheromatous degeneration or calcification may also become the seat of thrombosis. Dilatation of the heart and slowing of the blood stream are favoring factors in all of the conditions named above, but are probably not in themselves sufficient to cause thrombosis; the changes in the endocardium must be regarded as of prime importance.

Symptoms.—Thrombi of large size may exist indefinitely without serious impairment of cardiac efficiency. In the majority of cases the symptoms produced cannot be differentiated from cardiac insufficiency due to other causes. The physical signs are those of dilatation; in case of the blocking of a valvular orifice by the thrombus the heart's action is usually too weak to produce audible murmurs. The valvular vegetations may give rise to symptoms of stenosis or insufficiency. In the case of the ball thrombi so frequently formed in the left auricle in mitral stenosis sudden death or the most serious disturbances of circulation may be caused by the complete or partial blocking of the mitral orifice. The occurrence of embolism, either of the pulmonary or of the systemic arteries, is the symptom of greatest value in the diagnosis of cardiac thrombosis. Embolic abscesses may be produced throughout the body in the case of emboli arising from thrombi caused by pyogenic bacteria. In the case of a patent foramen ovale paradoxical embolism from thrombi in the right side of the heart may occur. In general it may be said that the diagnosis of cardiac thrombosis is usually impossible, having been made in but few cases. Aside from the occurrence of embolism the irregularity of the symptoms and physical signs may excite suspicion of a movable body within the heart.

The Prognosis is bad, not only because of the interference of the heart's action and the danger of embolism, but also because of the conditions which have led to the thrombosis. The treatment is directed chiefly to the latter and to the support of the heart.

Aldred Scott Warthin.

HEART, WOUNDS OF.—Wounds of the heart may be either non-penetrating or penetrating—injuring the cardiac wall or opening a cavity. The chief dangers from the former are shock and injury to a coronary artery. Ninety per cent. are penetrating, and of these only nineteen per cent. are immediately fatal. The right ventricle is most frequently injured, and the left auricle is least so. Auricular wounds are more fatal than ventricular, and injuries to the apex are less dangerous than either. A needle puncture will rarely cause hemorrhage from a ventricle, but excessive bleeding, which is mostly systolic, is liable to follow a like injury to an auricle. A wound inflicted during diastole is less dangerous than a similar injury during systole, perpendicular wounds are more fatal than diagonal, and those of the right heart bleed more profusely than those of the left. The presence of the foreign body in the heart, the size of the wound, the location of the wound, the number of wounds, the connecting cavities, the attending syncope, the involvement of Kronecker's co-ordination centre, are important factors in determining the outcome. Pericarditis, myocarditis, endocarditis, cerebral embolism, and empyema are frequent secondary complications. When the wound heals there is a possibility of cicatricial stretching, and subsequent rupture as in a case reported by Izzo of a man stabbed in the left ventricle, who was conveyed to the hospital from which he was discharged cured on the twenty-eighth day; a few hours afterward, while lifting a heavy body, he fell and quickly died. At the autopsy the cicatrix of the left ventricle was found ruptured. In addition to injuries of the heart caused by bullets, daggers, knives, needles, and various implements of war, it may be wounded by a fractured rib, by a foreign body that has perforated the œsophagus, or by blows upon the chest. Traumatic ruptures are more frequent after a full meal, as the distended stomach pushes the heart upward and forward, and causes a large area of the organ to be in contact with the thoracic wall and receive the impact.

Newton and Gamgee have collected forty-five cases in which traumatisms caused rupture of the heart without opening the pericardium. All were fatal. Only one of Gamgee's cases survived the injury fourteen hours. The fatality is easily understood, for, there being no exit, as soon as the accumulation of blood exceeds the limit of pericardial distensibility, the cardiac movements are mechanically stopped. The surgeon not only would be justified, but it is his bounden duty to operate upon every one of these cases, for it is more important, if possible, to rescue a drowning heart than to relieve a strangulated hernia. It is possible for a foreign body, as a gun missile, to remain quiescent for years in the myocardium, as in the case of a British officer, reported by Stevenson, who carried a bullet encapsuled for eleven years, or the still more remarkable case of Beers (Cincinnati *Lancet Clinic*, 1898), of an American soldier who survived the lodgment of a bullet in the wall of the left ventricle for thirty-seven years.

Symptoms.—There is no certain cardinal sign by which an injury of the heart can be denoted, but when we consider the location of the external wound and the usually profuse hemorrhage from it, if it is large, in connection with other signs and symptoms, it can generally be recognized. The pulse is weak, irregular, and intermittent, and often imperceptible in the extremities. There are pain, pallor, restlessness, and generally dyspnœa. Frequent attacks of syncope are common. The mind is clear but the countenance depicts an anxiety and distress that seemingly would welcome death, with the wintry sterility of the grave, as a sympathizing friend. If there is much blood in the pericardium the heart sounds are indistinct and percussion elicits increased dulness. With the pulsation of the heart a foreign body, as a needle, may be seen to move under the skin, a sign centuries ago enshrined in the magnificence of indestructible verse:

> "He fell, the spear point quivering in his heart
> Which, with convulsive throbbing, shook the shaft."

Treatment.—I presume no one will question the propriety of immediate operative interference, as experience teaches that about thirty-nine per cent. of cases recovered in which the heart had been sutured as against ten per cent. of recoveries in which no operation had been performed. The patient must be kept absolutely quiet. A probe should never be employed, as it is liable to inflict an additional injury upon the myocardium. For temporary hæmostasis some operators have recommended Pean's forceps and various modifications of it, but they all more or less lacerate the myocardium and can never replace digital pressure. Interrupted sutures are preferable in closing a wound of the myocardium. They should not involve the endocardium, and as few as possible should be passed, commensurate with safety against leakage, as they cause a degeneration of the muscular fibre with its tendency to dilatation and rupture. Giordano, from his experiments upon rabbits, concludes that auricular wounds might be closed advantageously with Lembert's sutures. Silk is preferable to any other material. The needle should be the same as that used in suturing the intestines. The sutures should be passed and tied during diastole. If the wound in the heart is sufficiently large a finger should be introduced into it, as Parrozani did, for the double purpose of checking the hemorrhage and to facilitate the passage of the first suture which should be used to steady the heart for the passage of the others. If the pericardial sac is closed either interrupted or continuous sutures may be used. It hardly seems necessary to accentuate the fact of the necessity of perfect cleanliness in these operations whenever the urgency of the case does not require instant intervention, as in the patients of Longo and Ninni. The question of administering an anæsthetic is a mooted one. Ollier says general anæsthesia should not be thought of. Parrozani operated upon his two cases without an anæsthetic, and observed only slight movement when he cut the skin and in passing the sutures in the myocardium. Giordano made the same observation in his case, but thinks Ollier's statement is too sweeping; and if the pulse is strong and the general condition good, chloroform may be administered. Struggling from an anæsthetic is liable to produce detachment of a clot, and renew the hemorrhage, as occurred in Parlavecchio's case. No two operators have made similar external incisions for exposing the heart. Professor Rotter performed a number of experiments upon the cadaver, and concluded that the easiest way to expose the heart was by making an incision four inches in length along the lower border of the third rib, commencing three-fifths of an inch to the left of the sternum. A similar incision was made along the lower border of the fifth rib. The external ends of these incisions were joined by a third. The fourth and fifth ribs were divided and the musculo-osseous flap was turned inward. If more space should be required the third rib could be included. No arteries excepting the intercostal require ligation in this operation. In Parrozani's successful operation an incision through the soft parts one and one-fourth inches from the margin of the sternum, in the fourth intercostal space, was carried for a distance of five and one-half inches, then it descended vertically in the mid-axillary line as far as the superior margin of the ninth rib. The fifth, sixth, seventh, and eighth ribs were cut through, in the mid-axillary line, the incision extending through the pleura. The flap, or door, was raised with the cartilages of the ribs acting as hinges. Parrozani closed the pericardial sac and sutured the flap in position. As the uncleanliness of the weapon and often the urgency of the operation preclude the proper preparation of the patient, it is considered safer to drain the pericardial sac with iodoform gauze as was done in the successful cases of Rehn, Ramoni, and Rosa. There are on record eighteen cases of heart suture and one of ligation of the left coronary artery. Five of these eighteen cases were injuries to the right ventricle and were stab wounds. In two of the cases the surgeons stated that the wounds were one-fourth of an inch and three-fifths of an inch in length. In two cases three interrupted stitches, in two four interrupted stitches were taken, and in the fifth case the wound was closed with a continuous suture of five stitches. Two of the patients recovered. Of the three unsuccessful cases, broncho-pneumonia caused the death of one on the sixth day, and in the other two cases the operators were not explicit as to the cause of death.

In one patient the left auricle was opened to the extent of four-fifths of an inch. It was closed with four silk stitches. Death occurred on the nineteenth day from abscesses in the lungs.

In three cases the dagger entered the apex, and in two of these it extended into the left ventricle. In these two cases the wounds were respectively three-fourths of an inch and one and a half inches in length; both were closed with four interrupted sutures. The wound which did not enter a cavity was closed with one stitch. All ended in recovery.

There are seven cases of stab wounds of the left ventricle. The length of these wounds varied from three-fifths of an inch to one inch and two-fifths, and required from two to four stitches. Two patients recovered, one died on the operating table of hemorrhage, one in fifteen minutes after reaching the bed, one of pericarditis several days after the operation, and the other two within twenty-four hours, never having reacted.

In two of the cases no mention is made as to the location of the wound. One was a shot and the other a stab wound of the heart. The patient that was stabbed died of empyema on the twenty-second day after suturing.

The left coronary artery was cut and ligated two hours after the injury. The patient had pericarditis and died thirty minutes after the second operation, which was performed on the fifth day for the purpose of drainage. After most of these operations stimulating hypodermic injections were used and hypodermoclysis and autotransfusion practised.

Dr. John B. Roberts, of Philadelphia, in 1881, suggested heart suture, and Dr. Del Vecchio, of Naples, in 1894, demonstrated its feasibility before the Eleventh International Medical Congress in Rome, by his experiments on dogs. Two years later the human heart was sutured by Farrina and Cappelen. It is surprising to find the statistics collected by Fischer, of Breslau, in 1868, quoted as late as 1901 as authoritative in computing the prognosis in this class of injuries.

The successful suturing of the heart by Rehns, Parrozani, Parlavecchio, Pagenstecher, and others has revolutionized the treatment and changed the probable outcome. Fischer's statistics, though a monument to his untiring zeal and energy, are now like an antiquated signboard on a discarded highway; but

> "Faith, fanatic faith, once wedded fast
> To some dear falsehood, hugs it to the last."

Luther L. Hill.

HEAT, ANIMAL.—See *Calorimetry.*

HEAT-STROKE.—(Synonyms: Sunstroke, insolation, thermic fever, *siriasis, coup de soleil, coup de chaleur, Hitzschlag, Sonnenstich, ictus solis, insolatio.*)

Definition.—Insolation is a disease whose main features are, in its milder forms, intense exhaustion, with or without rise of temperature, and in its severer forms, with an enormous rise of temperature and coma probably caused by acute auto-intoxication due to the presence in the blood of toxic decomposition products or toxic substances produced at the unusually high temperature, the exact nature of these substances being at present unknown.

From the time when it is recorded that Elisha restored the Shunammite woman's son to life after a sunstroke the frequency of this affection has often been noted. Armies at times have been almost decimated by it, especially when operating in sub-tropical or tropical countries. Sunstroke occurs most frequently in the tropics, particularly where the climate is damp. In the United States it occurs during summer in the Mississippi Valley, around the southern shores of the Great Lakes, and especially along the Atlantic coast. In the Western and Southwestern States it is rare, owing to the dryness of the climate.

Any cause that diminishes the resistance of the body predisposes to sunstroke. Alcoholism is undoubtedly the most frequent predisposing cause, not only chronic alcoholism but even a single excess. All causes producing extreme fatigue, such as severe muscular exertion and sexual excesses, predispose to an attack. Elderly people suffering from chronic ailments and invalids of any age, even if taking no bodily exercise and remaining indoors, are sometimes overcome by the heat and suffer true attacks of heat-stroke. It is not so common amongst children as amongst adults. Men are more frequently attacked than women because their occupations more often subject them to different forms of exposure to heat and require of them greater physical exercise, and because men are more often given to alcoholic excess than women.

Exposure to the direct rays of the sun is usually the exciting cause, but this is not necessary; some of the worst epidemics in the tropics have occurred during the night. While soldiers on the march and laborers working in the sun have given the greatest number of victims to this disease, men working in superheated environment such as firemen, stokers, and laundrymen have often been attacked. The main factors in the weather which are specially prone to assist in the causation of insolation are high humidity with continuously high temperature and lack of motion of the air. Humidity and especially the absence of cooling breezes are as important factors as is high temperature, although the cause of sunstroke is usually attributed to the high temperature alone. It has long been noticed that a hot, sultry, lifeless atmosphere is the one in which most cases of sunstroke occur. Impurity of the atmosphere is not unimportant, as is shown by the fact that men sleeping in crowded barracks or small tents are more often victims than those in well-ventilated quarters.

Sunstroke occurs with greater frequency in the tropics amongst unacclimated individuals than amongst those of long residence, who have acquired a certain amount of immunity to the effects of heat. This immunity, however, is by no means absolute, as even the natives of India, Egypt, Arabia, and Africa are at times overcome. The light-skinned races are more susceptible than the dark-skinned.

Pathological Anatomy and Pathology.—The post-mortem appearances depend on the time that has elapsed since death occurred. When the post-mortem examination is made shortly after death the following conditions are usually present: When the ante-mortem temperature has been high the viscera feel noticeably hot; the lungs are congested, often extremely so; the liver is large, and the abdominal veins are filled with blood and there is intense congestion of the brain and meninges. The left ventricle of the heart is contracted and empty; the right ventricle is filled with semi-fluid blood, sometimes giving an acid reaction. Rigor mortis has set in early. When several hours have elapsed since death decomposition has rapidly set in. The heart, instead of being contracted, is then flabby and filled with grumous, semi-fluid blood. The spleen is slightly enlarged and soft. The meninges of the brain are congested, and there is more or less abundant subpial fluid. The brain itself is usually firm and not congested, with sometimes a little bloody fluid in the ventricles. The membranes of the spinal cord are congested, the cord being firm and about normal in appearance. Small hemorrhagic extravasations are sometimes found in the viscera, pleuræ, and pericardium. The most constant changes seem to be marked congestion of the meninges and viscera, the fluidity of the blood, and the unusual rapidity with which rigor mortis and decomposition supervene.

In the minute cellular structure of the brain we find changes which are much more constant and which are fairly characteristic. Dr. Ira Van Gieson, of New York, has described these lesions in the neurons of the brain and cord, as an acute parenchymatous degeneration of the ganglion cells best shown by the Nissl stain and counterstain with eosin. In the normal cell stained in this manner the chromophilic plaques, or Nissl bodies, appear to have a somewhat barrel-stave shape and to be somewhat thickly packed in the body of the cell. In insolation the appearances are strikingly different. In the early stages of degeneration the chromophilic plaques are divided into large and small segments, and in other places appear fused together in a confluent condition, and they show changes in form, having rounded ends or are oval or spherical, and are abnormally few in number. In other cells the chromophilic plaques show further disintegration, and have been converted into fine, dust-like particles strewn about over the cytoplasm, giving it a finely granular, almost homogeneous appearance. The outlines of these cells are much less distinct than normal. These appearances seem to be more often found in the anterior horns of the spinal cord, where the changes do not seem to have advanced so far as in the cerebral cortex and cerebellum. When the changes are further advanced the chromophilic plaques are not only converted into dust-like particles, but in some cells the particles have disappeared, giving to the cell body a pallid, shadowy outline. The changes in the nuclei may also be marked and radical. The nuclear membrane is uneven in outline, notched in places, and slightly crenated; the nuclear fluid is changed in consistence, so that it appropriates methylene-blue stain very freely. This is in distinct contrast to the normal. In some cells the nuclear contents appear homogeneous, while in others there is a fine granular content. In some cells the nucleus seems to have entirely disappeared. In none of the ganglion cells of the cerebral cortex, cerebellum, and spinal cord which have been examined, has there been any distinct evidence of destruction of the cells. There have been no vacuoles nor loss of substance in the cytoplasm. The cells preserved their form, with the exception of the various phases of dissolution of the chromophilic plaques. In the cerebral cortex these changes occurred in both motor and psychic cells.

The changes thus described are simply those produced by the operation of a great variety of poisons, as lead, alcohol, the microbic poisons, and auto-intoxications. It is therefore evident that a chemical reaction has occurred between the poison and the constituents of the cells. By the method of elimination and excluding other groups of poisons, these changes having been found in the nervous systems of patients in whom alcoholism can be positively excluded, it is justifiable to conclude that the lesions found in cases of insolation are from some kind of auto-intoxication. This toxic resolution of the ganglion cells may not necessarily go on to destruction of the cells.

Recently L. W. Sambon has brought forward the idea that sunstroke is due to microbic infection, basing his opinion on the fact that the cellular lesions cannot be distinguished from those of microbic infections, and upon the symptoms, relapses, its peculiar geographical distribution, epidemic outbreaks, condition of climate and soil under which it prevails, and the relative immunity by acclimatization. He has given the name of "*siriasis*" to this disease.

The explanations of these reasons, advanced by this author, do not seem to be sufficient to justify this opinion, and the history and circumstances under which the various epidemics have occurred point strongly against the microbic origin.

The changes in the cells of the other viscera also seem to be those of acute parenchymatous degeneration. These are especially noticeable in the liver and kidneys. The blood in sunstroke also undergoes certain marked changes. The number of red cells seems increased, but this is probably only apparently due to the condensation of the blood from loss of fluids through excessive sweating. The hæmoglobin in twelve cases gave from eighty-five to one hundred and twenty-five per cent., averaging one hundred per cent. The increase above the average normal was probably also due to blood condensation. There seems also to be destruction of the red cells, as the leucocytes are found to contain pigment. The pronounced anæmia following sunstroke also bears out the destruction of the red cells. These blood changes occur not only in patients who have suffered from hyperpyrexia, but also in those whose temperatures do not rise above 105° F. As the red cells do not disintegrate from heat until the temperature rises to 125–129° F., the destruction observed in insolation points definitely to some toxic elements in the blood. The blood serum of sun-stroke patients has also been shown to be exceedingly toxic to animals. Levene and Van Gieson found that 9 c.c. injected into the ear veins of rabbits killed the animals in less than an hour, normal human serum having no such effect.

The gases in the blood, however, seem to remain normal. Wood and other observers have reported that the alkalinity of the blood in individuals dying of sunstroke is greatly diminished, and in some instances the reaction is distinctly acid. Levene and Van Gieson have also found that the urotoxic coefficient was diminished in the urine of sunstroke patients, while it was increased in the urine of the same patients during the first twenty-four to forty-eight hours of recovery. This seems to point to failure of elimination of toxic substances during sunstroke. Arloing has found that the sweat during severe muscular exercise is two or three times more toxic than that of the same individuals at rest. When sweating ceases in sunstroke there would seem to be an accumulation of these toxic substances.

Based on the above lesions and experimental observations, the clinical symptoms of the various forms of sunstroke are more readily explained and understood than by the theory that heat alone within the body was the sole cause. The changes in the cytoplasm in the ganglion cells show the injury to the functional activity of the cell, while the changes in the nucleus show processes detrimental to cell life.

The prodromal symptoms of the severe forms of sunstroke are those of severe functional disturbance, while the later symptoms of the severe forms show a tendency to destruction of the neurons. Heat undoubtedly is the main contributing cause of sunstroke, as exposure to cold is of pneumonia. From whatever source the heat comes the action on the body is practicallly the same.

The even temperature of the normal body is maintained by the maintenance of the equilibrium between heat production and heat loss. Young persons with healthy eliminative organs will stand a high degree of temperature and long exposure to the effects of heat. Equilibrium is secured by the contraction and dilatation of the skin capillaries and increase and decrease of perspiration, with the consequent increase and diminution in radiation and conduction of heat over the body. There are also said to be nervous centres controlling the production of heat, but their exact location and action are not fully determined.

Heat is produced in the body by chemic metabolism constantly acting, especially during muscular exercise. Normally 2.6 per cent. of heat is lost from warming food and drink ingested; 2.6 per cent. by warming the inspired air; 14.7 per cent. by evaporation; and 80.1 per cent. by radiation and conduction through the skin.

Sunstroke occurs with greatest frequency among persons performing some form of bodily exercise in an intensely hot environment. The heat production of the body is thus at the maximum, while the heat loss from warming the inspired air is zero. The loss from radiation and conduction is also zero, the air being as warm as or warmer than the body. If sweating is excessive heat loss may be sufficient to maintain the equilibrium; but if sweating ceases, as it usually does in insolation, heat loss ceases and heat production continuing, the heat rapidly accumulates in the body, and thus an enormously high temperature is brought about.

Goldscheider and Flatau have shown that the neurons of the central nervous systems of animals whose temperatures have been artificially raised to 109.4° F. seem to show the same changes when stained by the Nissl method as those described above. The neurons of living animals whose temperatures have remained for three hours at 107–107.6° F. also began to show the same changes.

But when the animal had been previously killed and the temperature of the body raised to 112.3° F., the cells did not change. Heat alone, therefore, will not produce these changes, and the action must be one of chemical metabolism in the living cell protoplasm. In sunstroke patients at times die, the temperature never having gone above 106°. This temperature in other diseases of microbic origin is borne without causing death, hence the amount of heat *per se* in the body does not cause death in these cases of sunstroke.

Most authorities state that a temperature of 113° F. is necessarily fatal, but a patient suffering from sunstroke was admitted to the Presbyterian Hospital, in New York, with a temperature of 115° F., and recovered. The limit of temperature which can be borne by the body with recovery can, therefore, not be definitely stated. In infectious diseases it is the lesion produced by the causal agent and not the temperature which kills; in sunstroke it is the metabolic changes in the central neurons and not the heat.

As to the definite cause of death in sunstroke, many theories have been advanced. Sudden coagulation of the cardiac muscle due to heat does not seem a tenable theory. While it is true that on the battlefield men have been known to drop from sunstroke and become rigid, dying almost instantly, heat coagulation of the heart muscle does not occur below a temperature of 122° F. or higher, while many patients die long before such a temperature is even approached, and the highest temperature ever recorded in sunstroke is 117.8° F. Death is also not due to lack of conduction in the nerve fibres, as these do not lose their power of conduction to impulses until a temperature of 125.6° F. is reached. It would therefore seem to be due to some toxic action on the cardiac and respiratory centres at whatever temperature this action may occur. In the most accurately recorded experiments on animals respiration ceased before the heart. Clinically there seems to be simultaneous failure of heart and respiration, but at times first one ceases, then the other. As will be seen later, the prodromal symptoms of insolation are those of disturbance of the digestive tract and liver. Food is badly assimilated, there is indigestion in the stomach and in the intestines, and sometimes slight jaundice. Abnormal substances are thus produced in the digestive tract and liver. This causes headache and malaise. When severe muscular exercise adds its decomposition products to the circulation and at the unusual high temperature of the blood, abnormal chemic changes may take place.

The milder forms of sunstroke known as heat prostration, or exhaustion, are therefore due to a mild form of auto-intoxication, and are but the prodromal period of the severe forms, the neurons being but functionally disturbed. If the intoxication is more severe, syncope and unconsciousness occur. Heat loss due to great dilatation of the skin capillaries is sufficient to prevent accumulation of heat. Heat loss may be so pronounced and predominate over heat production that lessening of temperature may occur. When the intoxication is very severe unconsciousness may develop suddenly with or without prodromal symptoms, and the vaso-motor, cardiac, and respiratory centres are affected. Heat loss being abolished, and heat production and accumulation being at a maximum, an enormously high temperature is developed. The neurons are so severely poisoned that their functions are abolished and convulsions, delirium, coma, and death supervene.

Symptoms.—The mildest form of sunstroke is heat prostration or exhaustion. An unusual weakness following exertion in hot weather most often seen in feeble persons is probably the mildest form that occurs. In more vigorous individuals the symptoms of this form are more pronounced. Exhaustion may come on suddenly without prodromal symptoms, or there may be prodromal symptoms followed by complete exhaustion. There are usually headache, dizziness, pain in the back and legs and epigastrium, with sometimes tingling of the hands and feet. These symptoms may continue for a few hours or for three or four days, and are sometimes accompanied by anorexia, nausea, and vomiting, or there may be diarrhœa or constipation. Some patients show slight jaundice of the whites of the eyes. Uncommonly in this form of sunstroke perspiration may cease. While the patients are suffering from the prodromal symptoms they may be able to sleep and awake refreshed, but as soon as they attempt to go about their usual occupations after a varying length of time the prostration becomes so extreme that they are forced to give in to it. The headache is intense, either frontal or occipital, and the patient seems dazed; consciousness is retained. The respirations are slightly different from normal, 24 to 28 per minute. The pulse may remain normal in frequency, or, depending upon the intensity of the exhaustion, it not infrequently runs as high as 130 to 140 per minute. It is, however, of good force and tension. The temperature may be normal or even slightly subnormal, though as a rule there is a rise and the temperature may reach 104.8° F. Under proper treatment the temperature may become normal in a few hours, the other symptoms abate, and the patient rapidly recovers, or the symptoms may continue and there may be a slight thermic fever for two or three days, even a week, the temperature ranging from 99° to 103° F., gradually falling to normal. Cases have been observed in which a slightly elevated temperature has been maintained for fifteen days.

In moderately severe cases there is always loss of consciousness, but the temperature does not reach the hyperpyrexial level of 105° F. The same prodromal symptoms may be present as in the mild form, and at other times there is an intense feeling of burning and heat and "pins and needles" in the head. Sometimes there are alternating hot and cold flashes over the body with sweating. Vomiting and anorexia are often severe. Perspiration may cease a short time before unconsciousness occurs. Just before loss of consciousness there are noticed in some patients sudden dizziness and dyspnœa, sometimes with chromatopsia. In other patients there is no premonition of the attack.

These symptoms may occur while the patients are at work or they may be suddenly overcome while quietly walking in the street at night. Suicidal tendency is sometimes developed just prior to loss of consciousness; sailors have been known to try to throw themselves overboard, soldiers to attempt suicide with their rifles. This temporary mental aberration may continue for a week or two, and then be followed by complete recovery. In some cases of this class there are, with the loss of consciousness, symptoms of complete collapse. Wood reports a case with a temperature of 95° in the mouth. Temperatures of 96–97° are not uncommon. The majority of these patients, however, show a rise of temperature between 101–104°. Except in cases of collapse the pulse is full and of good force and tension, though it may be as high as 130 per minute. Respirations may be normal or as frequent as 40 a minute, being usually shallow, the stertorous breathing of the severer forms is not present.

Physical examination will show coated tongue, skin hot and dry or covered with profuse sweat, and the patient may be conscious or totally or partially unconscious. The pupils react to light slowly and are sometimes dilated. Slight convulsive movements may be present, or there may be a restless delirium with moaning and groaning. Not infrequently there is a peculiar dark-pink, petechial rash on the body, different from the ordinary prickly-heat rash.

The changes in the blood enumerated above occur in this form of sunstroke as well as in the hyperpyrexial form. Unconsciousness, delirium, and other symptoms may persist for a few hours after the cold bath; sometimes consciousness is not regained for twenty-four hours.

Thermic fever when present persists for several days or a week. Patients usually recover from this form of sunstroke. This degree of insolation seems to be the least common. In two hundred and twenty-four cases of different types of sunstroke coming under the writer's notice in Bellevue Hospital in 1896, there were but eighteen of this type.

The severest form of insolation is the hyperpyrexial type. In this class are included all patients whose temperature rises to 105° F. and over, with or without loss of consciousness. The prodromal symptoms when present are often more pronounced than in the lighter cases, though many cases of this severe form of sunstroke have no prodromal symptoms at all. Patients whose temperature rises above 108° are less likely to have prodromal symptoms than those in whom the temperature is not so high. The worst attacks of sunstroke, therefore, may apparently occur without warning. The same prodromal symptoms are often present as in the milder forms. Insomnia, however, is marked, and may be present four or five days before the attack culminates. There are often great irritability and restlessness and sometimes decided increase in micturition for several days. A feeling of intense heat throughout the body, with the sensation as if the head were bursting open and the eyes bulging outward, is often noticed just before loss of consciousness. Chromatopsia is not uncommon, external objects taking on different colors, blue being the most common, or the field of vision may be occupied by brilliantly colored flames. In other patients objects suddenly lose color and appear black. Previous to loss of consciousness there are sometimes hallucinations of hearing or sight. Suicidal mania may also develop. Some patients are able to continue work which requires intelligent action and perform complex acts working with machinery, or may leave work and go home, undress, bathe, and go on the street again before falling helplessly inert, and yet after consciousness is regained retain no memory of what they had done for several hours previous to the time when they were seen to fall. When consciousness is retained the patients suffer intensely with burning heat and intense headache, and may become stupid and dazed. Retention of consciousness in these severe forms of sunstroke is the exception. In patients with a temperature above 109° I have never seen consciousness retained. Most patients are comatose. The skin is dry, flushed, and hot; or it is livid, pale, and cyanotic, and covered with cold, clammy perspiration. The glazed, set eyes are suffused and half open, or may be wide open and staring. The pupils are at times normal, or may be dilated or contracted unevenly. They may or may not react to light. Respirations come in short gasps, often irregularly, with a noisy, gasping inspiration and quiet expiration, or with explosive expiration and quiet inspiration, often accompanied with a piteous moan. Some cyanotic patients lie absolutely limp and flaccid, not moving even an eyelid, while in others there may be convulsive twitchings or violent epileptiform convulsions. Other patients with dry, hot skin are wildly delirious and fight and struggle furiously. In the limp patients the pulse is usually soft and frequent or small. In the more sthenic cases it may be full, strong, with throbbing carotids. The worst cases are pulseless. Vomiting and involuntary defecation are very common. The urine is scant, sometimes albuminous, sometimes containing blood. The peculiar petechial rash is often present, being most abundant upon the arms and body.

These sunstroke patients emit a peculiar, characteristic, disagreeable odor, particularly strong in the fæces, though it is distinctly not a fæcal odor.

The cyanotic type of sunstroke occurs more often with temperatures above 109° F. than below this figure. The height to which the temperature can go is unknown. The highest reported temperature is 117.8°, in a patient brought to the New York Hospital in 1896. Another patient in the Presbyterian Hospital, New York, had a temperature of 115°. These temperatures were measured with special thermometers. Temperatures of from 112 to 113° are not uncommon, and those of 108–110° are exceedingly common.

There is no exact ratio between the frequency of the pulse and the height of the temperature in these severe forms of sunstroke. With a temperature of 110° the pulse may vary from 90–150. The same is true when the temperature is 105–106°. The number of respirations per minute may vary from 16 to 50, irrespective of the temperatures.

In the most severe cases death rarely occurs immediately, but is delayed for a few hours. It has been stated that when the temperature is reduced the patient is out of danger, although the elevation of temperature may persist for some days. This is by no means true. While it is true that consciousness returns in about half the cases within an hour after the reduction of the temperature to normal, and when once regained it is retained, others do not regain consciousness until after two or more baths are given to reduce the continually recurrent rise of temperature, and many patients may remain unconscious for twenty-four hours or even as long as ten days and yet recover. In the worst cases, even after the temperature has fallen, the patients do not react but die within twenty-four hours; some, however, will live longer and die without regaining consciousness at the end of a few days. Others, after they have regained consciousness and are apparently doing well, at the expiration of a few hours or one or two days may develop delirium and remain delirious for a few days or a week and recover, or they may die during the second period of delirium.

Patients with a temperature of 105–107° frequently recover without thermic fever or any secondary rise of temperature. This exceptionally occurs when the initial temperature has been 107–110°. With temperatures above 110° there are one or more secondary rises of temperature which usually require active interference, or there is a continued fever for some time.

The secondary rises of temperature are apt to occur from three to six hours after the temperature has been reduced, sometimes not until from twelve to eighteen hours after the first bath. In serious cases the secondary rise may come on within an hour. It is not uncommon to find these secondary rises occurring eight, twenty-four, or thirty-six hours after the first bath. Some patients may have as many as four or five or even more exacerbations of temperature requiring active treatment. It is not uncommon to have thermic fever lasting for several days or one or two weeks, the temperature ranging between 101 and 103° F.

In severe cases after the bath the pulse remains feeble and soft and frequent. In favorable cases it drops more slowly to normal than the temperature. Among markedly alcoholic patients there is an asthenic course of the disease requiring special mention. The initial temperatures in these cases which have come under the writer's notice have varied between 106 and 109°, and the patients were strong, well-nourished individuals. They reacted well after their baths and became conscious within four hours, remaining rational for twenty-four hours; they then became wildly delirious or sank into the low muttering form. Their skin became dry and harsh, there was incontinence of urine and fæces. During the wild delirium their temperatures rose, frequently equalling in height the initial temperature, with a pulse of 120–150. In the low stage of the delirium the temperature did not rise above 102°, with a pulse of 80–100. In some patients just before death there was an ante-mortem rise of temperature to 106–110°. These patients died within *from three to eighteen* days after the sunstroke.

The convulsions mentioned as occurring in severe cases are not dependent upon the height of the temperature. They occur with temperatures of 105–106°, as well as with those of 108–112°, though they are more frequent with the higher temperatures; and since they seem to depend on the toxic destruction of the central ganglion cells, they are always of serious import though by no means fatal. They may be of a general epileptiform type, or they may be confined to the head, neck, arms, and legs. They may be more severe on one side of the body than on the other and rarely are distinctly unilateral.

While they may occur with the acme of temperature, they may not develop until some hours after the temperature has fallen. When the patient is in convulsion before the first bath the convulsions are apt to continue for some time afterward, though they may cease when the temperature becomes normal. Sometimes a second bath of a few minutes will cause them to cease. After they have disappeared and the patient has been rational for hours, or even one or two days, convulsions may suddenly recur and the patient may die in one. This is not uncommon. Muscular twitchings which do not develop into the convulsions are exceedingly common. An intense rigidity of the muscles similar to tetanic spasms is of quite common occurrence. This usually relaxes as the patient sleeps. These spasms may involve the respiratory muscles, and when they come on suddenly there is great danger of suffocation. The rigidity is often so great that artificial respiration is impossible.

The skin, in these cases of hyperpyrexia, often becomes dry and harsh during the week after the sunstroke, and desquamation may occur, the skin pealing off in large scales or flakes. Ecchymoses which occur in patients from bruising during the delirium are much more extensive than those occurring from ordinary bruises, and hypodermic injections of any substance are not infrequently followed by large ecchymoses which may go on to suppuration.

Complications.—Meningitis and encephalitis are not uncommon complications of sunstroke. Delusional insanity, with ideas of persecution and hallucinations of various kinds, are frequently observed. Pneumonia sometimes develops and is usually fatal. Fayer mentions that cerebral hemorrhage may follow sunstroke. Patients with chronic nephritis are very apt to have acute exacerbations of the nephritis and develop acute uræmia.

The sequelæ of sunstroke, even after the mildest forms, are often very pronounced. Not infrequently headache, extreme weakness, malaise, and dizziness are persistent. There may be soreness in the muscles and bones, with numbness and tingling of the hands and feet. This tingling may last for days or weeks, or even months. Anæmia is usually very noticeable. Polyuria, glycosuria, or diabetes mellitus may develop shortly after sunstroke and be permanent. Chronic meningitis with intense headache and stiffening of the cervical muscles or encephalitis with inco-ordination of the extremities, so that the patients may be unable to feed themselves, have all been seen following sunstroke. The nervous and mental conditions may develop into permanent dementia. Various forms of insanity, such as paresis or mania or delusional insanity, are recorded. Multiple neuritis may develop. Sometimes atrophy of a certain group of muscles, as, for instance, the flexor muscles of the forearm, may occur. Patients may develop a change of disposition, and from good-natured change to an ugly irritable disposition. Sensitiveness to heat, dizziness, and headache are probably the most common sequelæ. Chromatopsia on hot days may occur. Epilepsy may arise, and when previously present the fits occur with increasing frequency. Loss of memory and inability to concentrate the mind forces some patients to give up their work.

DIAGNOSIS.—Heat exhaustion may be confounded with internal hemorrhage, cardiac failure, and alcoholism. The intense headache of which the patient complains will aid in diagnosticating heat prostration. The moderately severe forms of insolation, especially with subnormal temperatures, restless delirium, and collapse, must be differentiated from internal hemorrhage and cardiac failure. The intensity of the delirium and twitching of the muscles will aid in recognizing the condition.

When unconsciousness is present the diagnosis from apoplexy, with its slow, full pulse, stertorous breathing, normal temperature, and local paralysis, can easily be made. In sunstroke we have a soft, frequent pulse, shallow breathing, and rise of temperature, and often hot, dry, flushed skin and absence of local paralysis.

The hyperpyrexial form may be confounded with meningitis, typhoid fever, and abscess of the brain with extremely high temperature. The usual excessive height of the temperature with the peculiar respirations, convulsive movements or intense convulsions, or the absolute immobility of the patient and the cool, clammy skin and high temperature, with the history of previous environment, should render the diagnosis easy.

PROGNOSIS.—The prognosis of heat prostration is universally good. In the moderately severe forms of sunstroke it is also good. The prognosis of the severe forms depends on the previous habits and condition of the patient. In alcoholics and those weakened by disease the prognosis is worse than in those of abstemious habits. The height of the temperature usually serves as a good criterion. When the temperature reaches 111° F. or over, the prognosis is very unfavorable, though by no means hopeless. With a temperature between 110–111°, if proper treatment can be appled quickly, about 50 per cent. recover. If proper treatment is not applied, very few recover with a temperature above 108°. Temperatures between 108 and 110° under good treatment have 75 per cent. of recoveries. With temperatures of 105–108° about 90 per cent. recover. These statistics are based on the death rate in 1896 among 520 hyperpyrexial cases. The death rate in those treated by hydrotherapy in various ways was 25.12 per cent. In 805 cases of all forms the mortality was 16.39 per cent. The mortality is usually given as from 41 to 50 per cent. In 961 cases reported in Aiken's "System of Medicine," the mortality was given as from 56 to 62 per cent.

The mortality in sunstroke depends greatly upon the rapidity with which treatment is instituted and also on the kind of treatment employed.

TREATMENT.—In the milder forms of prostration, if the patient is overcome in the sun, he should be immediately taken into the shade and if possible to a cooler place. The clothing should be loosened and the head bathed with cold water. If possible, ice should be applied to the head; this gives great relief to the throbbing headache. Aromatic spirits of ammonia, Hoffman's anodyne, or liquor ammonii acetatis should be given for stimulation. A little alcohol, such as a small dose of whiskey, is sometimes of benefit, though it is by no means as good as the other forms of stimulants mentioned. Iced tea and coffee are also excellent remedies here. Sipping very cold water will also revive a patient overcome with a feeling of faintness. Some of the coal-tar products are also valuable here to relieve the headache, such as phenacetin, in gr. v. doses; antipyrin, gr. x. to xv.; antifebrin, gr. iv.; and ammonol, gr. v. to x. If these can be mixed with a little sodium bicarbonate or caffeine they are excellent. The patient should rest, preferably in bed, for some hours until the feelings of faintness and dizziness have passed; he can then be allowed to go about as usual, being careful not to overexert himself and taking especial care to eat only easily digestible foods.

In the moderately severe forms, when collapse and subnormal temperature occur, the patient should be covered with blankets and hot-water bottles packed around the outside. The same stimulants may be given, and if the patient is unconscious hypodermic medication is necessary, gr. $\frac{1}{30}$ to $\frac{1}{60}$ of strychnine, gr. $\frac{1}{100}$ of glonoin, gtt. i. to ij. of fluid extract of digitalis, or gr. i. to ij. of a mixture containing ten per cent. camphor and ether can be administered. If the temperature is 103–104° and the patient is unconscious with convulsive twitchings, he should be placed in a cold pack, as a sheet wrung out of cold water, or put in a cold bath and vigorously rubbed for a few minutes, then dried and covered with blankets. If the temperature is not above 107° and is not relieved quickly, sometimes an enema of ice water acts with great benefit. One or two quarts of ice water, in which salt has been dissolved (one teaspoonful to the pint), will often, when used as an enema, bring the temperature down within an hour. But this ice-water enema will not control a rising curve of temperature. Headache in these cases can be controlled by the coal-tar products, which also aid in reducing the temperature, and by the ice cap.

The hyperpyrexial cases demand the most active and immediate treatment. Various forms of cold baths have been used. An ice bath consists of a tub of water in which about half a bushel of cracked ice is floating. Just before the patient is lowered into the bath the ice should be removed, as sometimes the sudden contact with the ice causes intense rigidity of the patient which brings on suffocation. This is rare, but it does occur; therefore the ice should be taken out of the bath before the patient is put in, but if the patient is put in ordinary tap water and rubbed a few moments, the ice can be placed in the bath while the patient is in it. During his stay in the bath the patient should be rubbed vigorously with rough mittens or the bare hand; sponges do not afford sufficient irritation; and as long as the patient is in the bath the rubbing should not cease. His head should be supported and cold water continually poured upon it. A towel folded over the forehead will prevent the water running into his eyes. Such a bath in a few minutes will cause the cyanotic skin of the patient to appear flushed and rosy; an unconscious patient may come to in the bath and the temperature will quickly fall toward normal. A thermometer should be constantly kept in the rectum of the patient in the bath, and the temperature should not be allowed to fall below 103° F. When this is reached the patient should be quickly taken from the water, rubbed dry, and covered up warmly. Hypodermic stimulation will be required in these patients. The ordinary results of this stimulation do not seem to be observed while the temperature remains excessively high. This should be remembered, as over-stimulation can easily be brought about, and this will occur when the temperature falls to a point near normal. For cardiac stimulation a dose of morphine, gr. $\frac{1}{8}$ to $\frac{1}{4}$, with gr. $\frac{1}{250}$ atropine, will be most beneficial. It diminishes the convulsions which are apt to follow and produces a sleep from which the patient wakes refreshed. Strychnine increases the tendency to convulsions, although it does not cause all the convulsions following sunstroke, as has been stated. Convulsions will occur in patients who have never had strychnine, but they do not appear so frequently as when strychnine has been used.

The length of time necessary for the reduction of temperature by these cold baths cannot be stated. It depends upon the amount of heat being produced, and not at all upon the height to which the temperature has gone. It may take twenty minutes to reduce a temperature from 106° to 103°, while a temperature of 110° may drop to 103° in five minutes.

Another method of reducing temperature is to place the patient on a rubber sheet and rub with ice. This takes much longer, and it only allows friction of the upper surface of the body and it does not reduce temperature so quickly or so effectively.

Still another method is to place the patient on a cot on a rubber sheet and throw dipperfuls of cold water over him from a distance of several feet. The impact of the water causes the necessary friction, and it is not an ineffective method. While it takes longer to reduce temperature, the reactions following it are not so marked as in the case of the ice bath, and when ice cannot be obtained it is the quickest substitute. While the water is being dashed over the body of the patient, cold water should be poured upon the middle of his forehead from a pitcher held six or eight feet above his head; this is most beneficial in bringing the patient back to consciousness. A very excellent method, perhaps the best, is to place the patient in a tub or on a cot or simply lay him on the floor and play a hose on him through a fine needle-spray nozzle. Where the head of water is sufficiently strong this is a most excellent method. It causes the physical irritation to the skin which is so essential to overcome the stasis in the capillaries. This stasis, according to Winternitz, prevents ninety-four per cent. of radiation of heat from the skin.

Patients treated in this manner should be allowed to have their temperatures fall to 102° or 101°; then they should be taken up, dried, blanketed, and put to bed. In severe cases the reaction following this method does not seem to be so intense as with the ice baths, nor so apt to fall below the normal. When the reaction occurs and the temperature goes to 105° the treatment should be repeated; an ordinary tub bath at 65° will sometimes control it. Warm baths have not proved so successful as the cold ones for reducing the temperature.

No treatment seems to prevent the thermic fever. A useful method of controlling this fever is to place small bladders filled with ice in the axillæ and groins; this seems more effective in women than in men.

After the patients are in bed, liquor ammonii acetatis is a most excellent stimulant and produces both diaphoresis and diuresis. Digitalis, ether, and spirits of ammonia are also excellent for rapid stimulation.

Among alcoholics the question arises as to the desirability of giving alcohol. When delirium tremens seems about to develop, as it so often does, a mixture of half an ounce of whiskey with one or two drachms of paraldehyde, repeated in an hour if necessary, will often produce sleep from which the patient will wake much improved.

It is best for twenty-four or forty-eight hours to keep the patient on milk, or at least fluid diet, followed by eggs, cereals, milk, and broth. Where there is severe thirst an abundance of water can be given. The liquor ammonii acetatis is useful in this connection to allay thirst. The sequelæ or complications of sunstroke should be treated as the same diseases under ordinary circumstances. The nervousness, weakness, and loss of appetite can be overcome by a mixture of tincture of nux vomica and compound tincture of cinchona, five to ten drops each, in compound tincture of gentian as a menstruum. For alcoholics, one or two drops of capsicum and sometimes ginger can be added to this mixture. Meningitis following sunstroke may have to be treated by a merciless use of the actual cautery. Patients suffering from sunstroke in the tropics may have to go to a more temperate climate or they may become helpless invalids. Such patients may develop some form of insanity, and it is well to remember the possibility of suicidal tendencies and never allow them to travel alone. The anæmia and general lack of nerve force following sunstroke can often be treated with cod-liver oil and small doses of tincture of iron. Of the latter, three drops should be put in a tumblerful of water and sipped with meals. This does not derange digestion and is preferable to large doses. Blaud pills or any other form of iron may be used.

The numbness and tingling so often complained of can often be benefited by the Charcot douche to the spine.

It is remarkable how long the sequelæ of sun-stroke may persist, and they are often discouraging to deal with. It is often years before exposure to heat can be withstood without recurrent headache and prostration.

Alexander Lambert.

HEAT, THERAPEUTICS OF.—Although heat has always been recognized as one of the most valuable therapeutic agents, it has never been so widely used as at the present time. It is one of the safest and simplest remedies known. Its good effects are varied and the methods of applying it are numerous. The results of the therapeutic use of heat are dependent upon various conditions, chief among which are the manner of its application and the temperature used. A far higher temperature can be borne when the heat is dry than when it is moist. For example, hot water becomes painful at 115° F. Steam or vapor cannot be borne above 120°, while hot dry air can be used at a temperature of 300° and higher. The vaso-dilator nerves are stimulated by heat, while the vaso-constrictors are inhibited.* The cutaneous capillaries are

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* This statement demands proper modification to express the facts as they appear. These are given in somewhat detailed manner in Armstrong's article on Baths in Foster's "Practical Therapeutics," and it is from this source that I have derived the information which is furnished in the following explanation:

In order that heat shall simultaneously cause stimulation of the dilated by a slow application of heat, but if the application is sudden the primary effect corresponds to that of cold, the skin is blanched and even wrinkled.

When the cutaneous capillaries are dilated the skin becomes reddened, and if the temperature is not higher than 104° F. cutaneous sensibility is increased. When, however, the temperature is increased to between 110° and 120°, sensibility is diminished or even abolished.

The nervous system is soothed by a moderate degree of heat, but untoward effects such as headache and vertigo are caused by a high degree if the air is not dry. The nerves to the sweat glands are excited by the application of heat, consequently the functional activity of these glands is increased and abundant perspiration is the result. The secretion of urine is proportionally decreased. The difference in the effects of dry and moist heat upon the perspiratory function depends upon the following facts. The body absorbs less heat from air than from water, and the skin perspires more freely in air than in water—the evaporation of the perspiration abstracting the heat—so that it is clear why it is possible to bear a higher degree of dry than of moist heat. The number of respirations is decreased by dry heat, but increased by a high degree of moist heat.

Although muscular activity is favored by a moderate degree of heat, a high temperature is depressing, and under its influence the muscular system becomes less able to support fatigue, especially if this is continued. A practical application of this fact is made in the treatment of the various muscular spasms, including chorea.

The effects of a hot climate depend upon the individual concerned and upon the various conditions of his life, such as diet, etc. It has been frequently noticed that debilitated persons are stimulated by a hot climate, becoming stronger and more able to ward off disease. Normal individuals are depressed, the effects being quickly seen in all of the functions of the body. In a temperature higher than that of the human body, body weight is diminished and in proportion to the degree of heat and the length of time of its application. This effect is less in dry heat than in moist heat. Hot applications to the abdomen cause constipation. This may be from two factors: from the decrease in intestinal secretions or from the decrease in peristaltic action of the intestinal musculature. Heat hastens eruptions.

There are many methods of applying heat, some of the appliances being as follows: bricks, water-bags, flat-irons, sand bags, Leiter's coils, and Paquelin's thermo-electric cautery. Moist heat may be applied by means of baths, both water and steam; douches, fomentations, and poultices; besides all of these methods there is the hot-air bath. The use of the hot flat-iron in such troubles as rheumatism gives astonishing results. The effects seem often magical, the relief afforded by this homely household remedy being greater than by many of the methods which are in more general use. The affected part should be protected by several layers of flannel, and in applying the iron it should be held carefully so that the weight is supported by the hand of the operator while the patient obtains the full benefit of the heat. The Paquelin cautery offers one of the best ways of applying counter-irritation. The hot bath produces various effects on the organism: by it the absorption of oxygen as well as the exhalation of carbonic acid is decreased; oxyhæmoglobin is reduced; so are the leucocytes; the excretion of nitrogenous products is increased. By means of hot baths interstitial combustion is diminished. In Bright's disease hot baths, on account of their weakening effect if often repeated, should not be employed unless dropsy or uræmia is present. When uræmia exists, however, the cerebral symptoms are often entirely relieved by the hot-water or vapor bath, for by this means not only the skin acts freely, but the effect on the whole organism is sedative, pain and irritability being allayed. Especially in childhood, various affections of the respiratory tract, such as bronchial catarrh, are relieved by this treatment. The sedative effect brings sleep and makes breathing less labored. The affected membranes are relieved of the surplus of blood, which is drawn to the periphery. The patient must be carefully watched and not be allowed to become weak from the treatment, as the secondary effects of a too long-continued hot bath are debilitating. However, continuous baths of moderate temperature are used in some affections, such as sloughing wounds and eczema; the patient eats and sleeps in the bath with the greatest comfort. For many years Kaposi, of Vienna, has employed the continuous bath in his wards with great success. Inhalation of warm vapor greatly relieves laryngismus stridulus. Diabetics should bathe in water of only a moderate temperature, and the bath must not be too long continued since this treatment may cause or increase glycosuria. One of the best methods of treating a strained joint, if seen early, is by the hot baths. Burns and phagedæna are much benefited by this method of treatment. Hot baths relieve the various forms of abdominal colic, as renal and hepatic; also inflammation of the urinary apparatus. In dysmenorrhœa, the hot foot bath is valuable. Heat applied to various regions of the spinal cord affects the organs which these nerves supply. This method is often successful in the treatment of metrorrhagia and menorrhagia. The Turkish and Russian baths are well known for their good effects in the treatment of many affections, such as coryza, gout, rheumatism, etc. But recently various new devices have been introduced by means of which the patient may be exposed with comfort to the beneficial effects of an extremely high temperature, for example 350° F., because the air is kept dry. Before apparatus was devised by means of which the air could be kept dry, the evaporated perspiration gradually rendered the surrounding atmosphere moist, and the perspiration on the skin actually scalded it. On this account the Turkish bath cannot practically be higher than about 170° F. The diseases that have of late years been treated with benefit by the new apparatus are the arthritic diseases—rheumatic arthritis, gout, rheumatism, etc.; joint affections, such as sprains; affections of the nerves, as neuralgia, sciatica, etc.; certain skin diseases; chronic ulcers, and flat foot.

There is other apparatus by means of which the body is subjected to the action of radiant heat. The diaphoretic effects of combined heat and light are said to be much greater than the same degree of non-luminous heat. The effect of the electric heat waves is invigorating and tonic. One result of these exposures to extremely high temperatures, one that is contradictory to former physiological teaching, is that the body temperature is raised several degrees. The following suggestion has been made in explanation of cases in which certain parts of the body are exposed to the heat: "It is probably due to imperfectly co-ordinated diaphoresis in parts of the body other than that exposed to the direct heat of the bath—that is to say, the blood as it flows through the heated area is not completely cooled down before it passes on to other areas, where the conditions are different, and where reflex, superficial, vascular dilatation, and consequent diaphoresis, are not correspondingly established." In the application of these new methods just mentioned, the apparatus is so arranged that the head of the patient remains free in the normal room temperature. Besides great local benefit, the general health is improved by these hot baths. In the radiant-heat bath the perspiration, as soon as it appears, is evaporated by the hot dry air. If this heat is applied locally, the circulation of the

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vaso-dilator nerves and inhibition of the vaso-constrictors the temperature employed must not be above 104° F., for it must be remembered that it is a *moderate* degree of heat that stimulates the vaso-dilator nerves and inhibits the vaso-constrictors. The cutaneous sensibility is increased and the skin is reddened. When the temperature is increased from 110° to 120° F., sensibility is abolished or decreased. It is from the knowledge of this fact that certain diseases of the nervous system are treated by the application of great heat. The effects also vary according to whether the application is slow or sudden. In the first instance the capillaries are dilated; in the latter the vessels of the skin are contracted and the skin becomes pale as in the application of cold. This fact is taken advantage of in bathing, where *very* hot water applied for a very short space of time stimulates the cutaneous nerves but does not call for the same vigorous reaction as a cold bath demands.

part treated is increased and not only is extra nutrition supplied, but a greater amount of blood is carried away from the part; and it is probable that this blood takes away from the diseased area many morbid products in solution. When radiant heat is produced by electricity, the advantages can be clearly seen, as there is no combustion and the patient breathes perfectly pure air. Among the affections treated with benefit by this method are the following: rheumatoid arthritis, gout, chronic cramp, sciatica, fixed joints, inflammation of the veins, adhesions following fracture, chronic articular rheumatism, chronic alcoholism, rheumatic gout, stiffness following injury, gonorrhœal rheumatism, vaso-motor disease, epilepsy, chronic Bright's disease, asthma, bronchitis, strumous ulcers, fracture, spinal disease, chorea, and peripheral neuritis. The general effect of the radiant-heat and light bath is soothing, as it allays pain and imparts a feeling of well-being.

The douche is used chiefly in gynæcological, nasal, and aural troubles. For pelvic inflammations and congestion the hot douche is most valuable. The good effects are dependent upon the temperature used, and upon the length and the manner of application. The temperature of the irrigating fluid should be as hot as can be borne. The application should continue for at least twenty minutes and the patient should lie on the back with the hips elevated.

By fomentation or cataplasm is meant the application of cloths wet with whatever liquid is used and applied to the part. The heat may be maintained either by renewing the cloths or by applying a hot object, such as a water bag or a brick to the cloths.

Poultices are not used now nearly so extensively as they were formerly. If they remain on the part too long they will lower the vitality and produce vesication or pustulation.

Heat has many specific uses, some of the principal being as cardiac stimulant, counter-irritant, diaphoretic, general sedative, general stimulant, germicide, hæmostatic, hypnotic, local anæsthetic, and local sedative.

Some of these effects have already been touched upon. As a cardiac stimulant heat is used universally in cases of shock and collapse, in drowning, exhaustion, asphyxia or debility of the new-born, narcotic and other forms of poisoning, in chilling if the patient is not frozen, and in any condition of heart failure. It may be applied in the form of baths, enemata, drinks, cloths, bags, bricks, friction, etc. In the algid state of cholera, for example, it must be remembered that clothing does not supply heat, it simply prevents its dissipation, so that special measures should be taken to impart heat to the body, as surrounding it with hot-water bags and the like. Death from chloroform anæsthesia is nearly always in consequence of heart failure. In such a case hot applications should be made to the cardiac region. External heat draws the blood to the periphery and thus relieves the heart.

As counter-irritant, it promotes absorption and hastens repair; it also removes passive congestion. In this connection it is often applied in the form of the actual cautery. This treatment is more valuable in chronic than in acute inflammation. It is sometimes indicated in deep-seated inflammation of the joints. The superficial layers of the skin only should be irritated. The cautery should be brushed over the part lightly, and be used at a white heat when vigorous counter-irritation is desired, but at a cherry-red heat for hemorrhage. The relief from its use is often as great as it is sudden. It is indicated in neuralgia and rheumatism. Its action may be reflex through the nerves, producing a change in the nutrition of the part, with promotion of absorption.

The value of heat as a diaphoretic has already been spoken of.

It is a good general and local sedative. It draws the blood away from the great vessels to the periphery, dilating the vessels of this region and producing a feeling of general comfort. It is also used in the treatment of neuroses. Hot applications to the face in toothache are very soothing. This treatment also relieves itching.

Its general stimulating effects have been spoken of.

Heat is the most trustworthy germicide that we have. It may be used in the form of fire, dry heat, boiling, streaming or live steam, and steam under pressure. Fire is used only to destroy articles. All pathogenic organisms and their spores are destroyed in boiling water in five minutes. Streaming or live steam is utilized in the ordinary sterilizer or disinfector. Steam under pressure is used to disinfect bulky objects such as bales of goods.

Heat is used as a hæmostatic in the form of the actual cautery or of water raised to the temperature of 120° to 140° F. If the bleeding surface is large, the oozing should first be treated by compression with hot cloths to stop the capillary hemorrhage before the cautery is applied. The clamp and cautery method of treating hemorrhoids is well known.

Heat is hypnotic, hot baths being very beneficial in acute and chronic insomnia.

A high degree of heat may be used as a local anæsthetic, since it has the faculty of blunting the perception of different kinds of sensation at certain temperatures, as mentioned before.

Although the uses of heat are at present so varied and valuable, this field is probably yet but in its infancy, as new discoveries and improvements are constantly being made in this department of therapeutics.

Emma E. Walker.

HEDONAL, methyl-propyl-carbinol urethane, occurs as a white, crystalline powder insoluble in cold water, slightly soluble in warm water, and somewhat more so in alcohol. It has a persistent, rather unpleasant taste suggesting mint, and on boiling with an alkali decomposes, forming ammonia, carbon dioxide, and methyl-propyl-carbinol. There are many reports on the hypnotic properties of this substance, Goldmann, Nawrateski, Arndt, and others claiming for it valuable powers without any undesirable after-effects. Brownrigg, also Schüler, found it a feeble hypnotic, useful only in cases of moderate nervous irritability. In nine of Brownrigg's thirty-five cases, and in five of Schüler's twenty-one, no sleep resulted from its administration. Raimann found the lethal dose in a series of animals to be 1 gm. per kilogram of body weight. Moderately large doses were followed by depression of circulation, respiration, and temperature. Nawrateski and Arndt point out that the drug is so diuretic that it may cause such a desire to urinate as to arouse the patient. All things considered, this drug is of less value than its congener, ethyl-urethane. The dose is from 1 to 3 gm. (gr. xv.–xlv.) given dry on the tongue and washed down with aromatic water, or given in syrup, in capsule, or in cachet.

W. A. Bastedo.

HEILBRONN MINERAL SPRINGS.—Bradford County, Florida.

Post-Office.—Starke. Hotels and boarding-houses in Starke.

Access.—Viâ the main line of the fifth division of Seaboard Air-Line Railroad, forty-five miles from Jacksonville. Also viâ Suwannee River Division of the same system. Starke, the county seat of Bradford County, is located on the elevated backbone of the Florida peninsula at an elevation of 180 feet above the ocean level. The location is surrounded on all sides by an almost unbroken pine forest stretching to the Atlantic on the east and the Gulf on the west, about fifty miles in either direction. The waters to the west flow into the Suwannee River and thence into the Gulf, while those to the east find their way into the St. John's River and ultimately reach the Atlantic. The situation thus unites many of the advantages of a well-favored natural sanatorium and offers an attractive resting place for the winter tourist in search of a genial and balmy climate. The mean temperature for the months of December, January, and February during a recent winter was 52° F. The rainfall for this period was 10.22 inches. Starke has a population of about 1,200 and is well supplied with schools, churches, livery stables, banks, hotels, boarding-houses, etc. The springs are located about five and one-half miles northwest from Starke on a picturesque stream known as the Wateroak, from the presence of numerous trees which adorn its banks. They are reached by an excellent road. The springs are two in number, known as No. 1 and No. 2. No. 1 yields about one hundred and fifty gallons and No. 2, fifty gallons per minute. The following analyses were made by Prof. Henry Leffmann of Philadelphia:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Spring No. 1. Grains.	Spring No. 2. Grains.
Sodium chloride	2.08	1.42
Sodium carbonate	.40	.60
Potassium carbonate	.20	
Potassium sulphate	.17	
Calcium carbonate	5.13	5.83
Magnesium carbonate	.20	3.73
Ferrous carbonate	.33	
Silica	1.51	1.51
Nitrogen by permanganate	.20	Trace.
Iron oxide and alumina	....	.23
Total	10.22	13.32
Gases.		
Dissolved oxygen	.92	.67
Dissolved carbon dioxide	11.70	12.30

These are excellent waters of the light saline calcic type. No. 1 also possesses ferruginous properties. We have carefully examined the water of No. 1 and find it to be very palatable and well adapted to table uses. Though not heavily mineralized these waters have acquired an extensive reputation among Florida physicians in the treatment of dyspepsia, chronic skin diseases, and rheumatism. Many practitioners recommend their local use as a lotion in ill-conditioned sores and indolent ulcerations. The waters are now used commercially and are bottled and shipped to distant points.

James K. Crook.

HELLEBORE, AMERICAN. VERATRUM VIRIDE. *Indian Poke, Itch-weed.* ("Green hellebore," but not to be confused with *Helleborus viridis.*) The dried rhizome and roots of *Veratrum viride* Ait. (fam. *Melanthaceæ* ["*Liliaceæ,*" U. S. P.]). The plant is a large, conspicuous swamp herb, having a simple upright, leafy stem, from 50 to 150 cm. high (2 to 5 feet), and terminating in a large spicate panicle. Leaves, 3-ranked, large, ovate, or broadly oval, pointed, sessile, clasping at the base, from 15 to 40 cm. long. Flowers monœciously polygamous, regular, 1 or 2 cm. across, spreading. Perianth of six narrow, pointed segments; stamens six; anthers extrorse, opening transversely across the top; carpels three; fruit of three many-seeded follicles. The whole plant is slightly pubescent, and of a bright, light-green color, flowers and all. It grows abundantly in marshes and along brook-sides in the cooler parts of North America—the Northern United States, Canada, and Alaska. Its common neighbor, and a plant which might be mistaken for it, is the skunk cabbage, but that has subrotund leaves, at least as broad as long, and they lack the conspicuous plaits of veratrum. The hairs of veratrum are slightly irritating to the skin of many persons, whence the name "itch-weed." Varieties apparently identical with it are found in Alpine districts in Europe and in Eastern Asia. The type of the species, *V. album,* replaces it in Europe and Asia generally.

The poisonous properties of this plant are said to have been known to the aborigines, by some tribes of whom it was used as a sort of ordeal to test their strength and vigor. "He whose stomach made the most vigorous resistance, or soonest recovered from its effects, was considered the stoutest of the party and entitled to command the rest" (Bigelow, "Med. Bot.," quoting Josselyn). It was also one of the numerous things used by the early settlers to poison seed corn for protection against birds; it is still occasionally so used. In the early part of this century it was employed as a substitute for *V. album* in gout, rheumatism, etc., in the treatment of which that substance was then popular, and also as a parasiticide, for which purpose both have been superseded by veratrine and other things. Its modern use as a cardiac depressant is of the last half-century only.

The rhizome, which is the part used, is collected in the autumn and generally split longitudinally to facilitate drying, but it may be variously cut or left whole; the roots, to the length of 10 or 15 cm., are left attached, and dry in a skein around its lower end. The officinal description is as follows:

Rhizome upright, ovoid or obconical, 2.5 to 7 cm. (1 to 3 in.) long and two-thirds as broad, externally light- to dark-brown or blackish, frequently bearing at the summit some coarsely fibrous remains of leaf-bases, densely clothed at the sides with coarse roots; internally grayish- or yellowish-white, exhibiting numerous short, irregular wood-bundles; roots about 10 to 20 cm. (4 to 8 in.) long and about 1 or 2 mm. ($\frac{1}{25}$ to $\frac{1}{12}$ in.) thick, light yellowish-brown, much shrivelled, the surface somewhat reticulate-wrinkled; inodorous, but the powder highly sternutatory; taste bitterish, and very acrid.

It is very difficult to distinguish the *V. album* from this, and impossible when they are powdered. *V. album,* if fresh, is lighter-colored, and its roots are thicker, fewer, more spongy, and more reticulate-wrinkled. The properties are apparently identical.

Besides containing resin and starch, veratrum has a complex alkaloidal composition, regarding which authors are not agreed. The individual alkaloids are only of theoretical interest, as they are not used, only one of them (jervine) being listed, and that for experimental purposes.

Jervine ($C_{26}H_{37}NO_3 + 2H_2O$) is a whitish powder, soluble in alcohol.

Pseudojervine ($C_{29}H_{49}NO_{12}$) is very similar to it and slightly soluble in absolute alcohol, while *Veratroidine* ($C_{51}H_{78}N_2O_{16}$) is alcohol-soluble. There is a very little *rubijervine,* which strongly resembles the last.

ACTION AND USE.—The action has been studied with care by several Americans, especially by Dr. H. C. Wood, from whose "Therapeutics" this paragraph is largely condensed. His experiments were made with jervine and Bullock's "veratroidine."

The symptoms of poisoning with the former in animals are sluggishness, muscular weakness, and tremblings, followed shortly after by violent convulsions and great prostration. Sensation is affected only very late, and consciousness almost not at all. There is no purging or vomiting, but always profuse salivation. Death occurs from cessation of respiration. Jervine is an intense cardiac sedative, acting both directly upon the muscle of the heart or its local ganglia, and indirectly through the general vaso-motor system. It reduces the force of the heart beats and the arterial pressure to a very great degree. The rapidity of the heart is also diminished while the animal is quiet, but even slight exertion raises it to rapid and incoherent action. There is also in jervine poisoning a marked reduction of spinal reflex. It is not locally irritating. The other alkaloid, "veratroidine," resembles jervine in its general action, but is a local irritant like veratrine and produces generally vomiting and diarrhœa, which the other does not. It stimulates the pneumogastric, and for a while increases the arterial pressure. The crude drug has naturally the combined action of its two alkaloids, and within its medical limits produces in man weakening and infrequency of the pulse, lassitude, and increase of salivary and cutaneous secretions, lowering of temperature, and sometimes vomiting. None of these effects should be pressed beyond a moderate degree. Its utility is limited by conditions requiring these modifications—that is, quick, hard-bounding pulse, febrile excitement, high temperature, and dry skin—conditions found only in the early stages of acute febrile diseases in robust or plethoric patients—in the beginning of pneumonia, pleurisy, rheumatism, etc.; in the hypertrophic stage of cardiac disease it may be needed, but not often; in typhoid, septic, and other adynamic febrile conditions it should never be given, nor as an emetic.

In overdoses the vomiting, purging, and prostration are best combated by opium and stimulants, with a strictly enforced recumbent position.

ADMINISTRATION.—The dose of the substance itself is about a decigram (gr. iss.), repeated rather frequently and in increasing doses until the pulse is affected. During the administration the patient should be carefully watched. Once an hour is a good interval for the first few doses. The following good preparations are official: The fluid extract (*Extractum Veratri Viridis Fluidum*, U. S. P.), and a tincture (*Tinctura Veratri Viridis*, U. S. P.), strength 40 per cent., dose ♏ ij. to x.

W. P. Bolles.

HELLEBORE, BLACK.—HELLEBORUS NIGER. *Christmas Rose.* The dried rhizome of *Helleborus niger* L. (fam. *Ranunculaceæ*). This is a low perennial herb of Southern Europe, mostly in the mountains, and largely cultivated for its winter bloom.

The drug much resembles cimicifuga or black cohosh, but is rather smaller, blacker, and more tortuous, with fewer and broader wood-wedges in the rhizomes, and those of the roots less conspicuously stellate. It contains the two poisonous glucosides helleborin and helleborein, and has been used as a drastic. In overdoses it is an emetico-cathartic poison. It is now little used. The dose is 0.5 to 1.5 gm. (gr. viij.–xx.).

The rhizome of *H. viridis* L. or green hellebore (but not to be confused with *veratrum viride*, also so called), is very similar, and even more highly acrid and poisonous.

Henry H. Rusby.

HELLEBORE. (TOXICOLOGICAL.)—Green Hellebore (Veratrum viride), *American hellebore, Indian poke*, and White Hellebore (Veratrum album), the European species, owe their poisonous properties to several alkaloids which have been examined by a number of investigators. The results are not entirely accordant, and what is doubtless the same substance has received different names from the different writers. The researches of Wright and Luff and of Salzberger are of particular value. Wright and Luff found in veratrum viride, jervin, cevadin (crystalline veratrin), pseudojervin, with traces of rubijervin and veratralbin. Salzberger found in V. album, jervin, the pseudojervin and rubijervin of Wright and Luff, and two other bases, protoveratrin and protoveratridin, but no veratrin.

The official veratrin, obtained from sabadilla, and which melts at about 147° C., is a mixture of two isomeric alkaloids—the crystalline veratrin or cevadin of Wright, which melts at 205° C., and amorphous veratridin, melting at 143–148° C. Crystalline veratrin or cevadin crystallizes with difficulty, is readily soluble in alcohol, ether, and chloroform, and insoluble in cold water. It has a bitter, disagreeable taste and excites violent sneezing. It combines with acids to form salts, which are generally non-crystalline. The reactions for the official alkaloid and crystalline veratrin are substantially the same. Sulfuric acid gives a series of colors—yellow, orange red, carmine red. If heated, the latter appears at once. Hydrochloric acid produces no color in the cold, but on heating a fine red is obtained which is quite permanent. Sulfuric acid with sugar or with furfural gives a yellow, changing to an indistinct green, dark blue, and finally to violet. Nitric acid gives a transient rose pink; on evaporation and moistening with alcoholic potash a brown color is obtained.

Physiological Test: A minute quantity of veratrin injected hypodermically in a frog causes vomiting, slowing of heart beat, and contractions of the muscles, suggesting the tetanic convulsions of strychnine.

Jervin forms white crystals which melt at 238° C., and have a bitter, acrid taste. The alkaloid is non-sternutatory. It is readily soluble in alcohol and chloroform, less soluble in ether, and insoluble in cold water. Sulfuric acid gives a yellow, changing to greenish-yellow and greenish-brown with green at edges. On heating, a mahogany-brown appears at once. Sulfuric acid with sugar or with furfural gives a brownish color, changing to a deep blue and then to an indistinct violet. Hydrochloric acid gives no color in the cold; on heating, a yellow is obtained. Nitric acid, followed by alcoholic potash, gives the same reaction as does veratrin.

Experiments upon animals show that both hellebores first excite, then paralyze the sensory nerves of the skin and of the mucous membranes of the nose and alimentary tract. Both respiration and the action of the heart are first accelerated, then retarded, and finally paralyzed. The symptoms, which usually appear soon after taking, are burning in the mouth extending to the stomach, difficulty of swallowing, intense nausea, violent vomiting, and later purging, usually accompanied by tenesmus. Great prostration follows, headache and giddiness are frequently present, the pupils are slightly dilated, the pulse is feeble, respiration is difficult and sometimes fails entirely. Death may occur from heart failure or from exhaustion caused by vomiting.

Several homicidal cases have occurred in Europe, notably in France, but the only cases reported in this country are accidental. Thirty-six drops of the tincture of veratrum viride, taken in divided doses, caused the death of a child of one and one-half years. A teaspoonful of the tincture, seventy-five drops of Tilden's fluid extract, sixty drops of Norwood's tincture in divided doses, and an unknown quantity of the tincture, taken by mistake for whiskey, have caused the death of adults. Recovery has followed the taking of much larger quantities. On several occasions, a teaspoonful of the fluid extract (H. C. Wood) and a tumblerful of the tincture have been taken without fatal results. One-half ounce of powdered white hellebore has been taken with recovery. No death from veratrin is on record. The different preparations are evidently of greatly varying strength. One sixteenth of a grain nearly caused death, while recovery has occurred after taking three grains in a liniment and thirty grains of the crude alkaloid.

The treatment of a case of poisoning will vary with the nature of the symptoms. Vomiting, so commonly present, will have emptied the stomach; if it has not occurred, it should be induced until the object is reached, then restrained. Warm drinks and external warmth are used to raise the temperature and opiates to control pain. Alcohol and aromatic spirits of ammonia are useful in meeting the extreme prostration. The latter precipitates the insoluble alkaloids and thus retards absorption. Artificial respiration may be required.

Post-mortem examination discloses the intestinal tract usually congested and the viscera filled with blood, as occurs with many other poisons. There is an absence of characteristic appearances.

For the recovery of the poison, the contents of the stomach, or the tissues, after suitable comminution, are digested on the water bath with alcohol and acetic acid for some time, filtered, and the alcohol is removed by evaporation. The residue is extracted with water, filtered, and shaken with ether to remove fatty matters and extractives. It is then shaken with chloroform, rendered alkaline with sodium hydroxid, and after repeated shaking the chloroform layer is separated and evaporated. It is generally advisable to repeat this process to remove impurities, and on evaporation the veratrin will be found sufficiently pure for the application of the tests.

Brouardel isolated from a corpse of eighteen months, a ptomaïn which was extracted from alkaline solution with ether. It gave a violet color when heated with sulfuric acid and a cherry red on boiling with hydrochloric acid. This suggests the importance of confirming the chemical tests by the physiological test.

Curtis C. Howard.

HEMERALOPIA AND NYCTALOPIA, respectively, day-vision=*night-blindness*, and night-vision=*day blindness*, from ἡμέρα, day, νύξ, night, respectively, and ὤψ, eye, are names used by the older medical writers in opposite senses, to the great confusion of the literature of the subject. Following Hippocrates, Aristotle, and Galen, although in opposition to the usage of later Greek authors,[1] nyctalopia is a condition in which vision is comparatively good at night, or in a very feeble light, but is defective in strong daylight; and, conversely, hemeralopia (used, in contradistinction to nyctalopia, in a single passage in Galen[2]) is a condition in which vision is acute by daylight, but falls off disproportionately at night. If certain recorded observations are to be accepted as trustworthy, it would seem necessary to admit that hemeralopia may occur under two types, the one marked by a quasi-diurnal fluctuation in the perceptive power of the retina, the other directly dependent on changes in illumination. Thus, it has been stated that the acuteness of vision increases from early dawn to the middle of the day, and diminishes as the sun declines toward evening,[3] falling to its minimum as twilight deepens into night, or, according to some writers, not until midnight;[4] that the blindness is less marked in the early dawn than in twilight,[5] and that in aggravated cases the flame of a candle, the stars, and even the moon are either totally obscured or are seen as through a thick smoke or fog (Nachtnebel[6]). As a rule, however, luminous bodies are seen distinctly, while objects at a little distance from the lamp appear enveloped in deep gloom, so that the light of the full moon may be insufficient to enable the hemeralope to see his way.[7] By concentrating the light of a powerful lamp upon the book, the hemeralope may be able to read large print; in other cases reading by artificial light is impossible.[8] That the falling off in vision at night is closely related to the defective illumination is proved by the fact that it occurs in the daytime on entering a dark room, although with some persons, as it would seem, in a lesser degree than at night.[9] Experimental tests of the vision of hemeralopes, by varying degrees of illumination, have shown that it begins to fail under nearly the same conditions as with normal-seeing persons, but that on further diminishing the light the falling off in vision, as measured by the size of the test objects which can be discerned, is much more rapid.[10] The hemeralope requires also a relatively long time to attain his maximum of visual acuteness on going from full daylight into a darkened room;[11] on the other hand, some hemeralopes suffer from dazzling of the eyes on first going out into the sunlight.[12] The condition would appear, therefore, to be essentially one of dulled perceptive power (*torpor retinæ*), which may, in certain cases, be conjoined with some degree of retinal irritability. This view is, moreover, in accord with the seemingly well-attested fact that the same combination of causes may give rise to hemeralopia in certain persons, and to more or less distinctly marked nyctalopic symptoms in others.[13]

Hemeralopia is an almost constant symptom in certain affections of the retina, notably in retinal degeneration with stellate deposits of pigment (*retinitis pigmentosa*), in syphilitic retinitis, and in incipient detachment of the retina; and it is then associated with particular limitations of the visual field, characteristic of the special retinal disease, and very often also with marked falling off in the acuteness of vision in full daylight (see *Retina, Diseases of*). Rarely it is congenital, and it may then be an early symptom of pigmented retina, or perhaps of retinal degeneration in which the usually characteristic pigmentation may be absent.[14]

Idiopathic hemeralopia has been oftenest observed as an acute epidemic affection attacking large numbers of persons living under nearly identical abnormal conditions. De Sauvages mentions such an epidemic as having broken out among the soldiers in several garrison towns bordering on one of the smaller rivers in the south of France, not far from Montpellier.[15] Other extensive epidemics have been observed, occuring almost always in large bodies of men crowded together under unfavorable hygienic conditions conjoined with excessive exposure to the direct influence of strong sunlight. Thus soldiers in garrison, going habitually from crowded, and often very dark, quarters in casemates to drill for hours together on confined and unsheltered parade-grounds, seamen and marines on tropical stations, prisoners employed in stone-breaking or other outdoor work in courtyards enclosed by high whitewashed walls, also children in great public orphan-houses, have been especially subject to these visitations, while the officers, whose duties ordinarily involve much less exposure, and who are better nourished and lodged, also the inhabitants of garrison towns, have generally escaped. Hemeralopia has been described as endemic in certain localities in the East and West Indies, in Brazil, on rice plantations in China, in several provinces of France, in the countries bordering on the Mediterranean, in Podolia toward the end of winter, and also in midsummer among the harvesters of both sexes;[16] also in the Russian provinces bordering on the Baltic, at the period of the very strict Lenten fasts of the Greek Church.[17] An outbreak of hemeralopia, associated with cases described as nyctalopia, is reported by Carron du Villards as having been observed by his father, in 1793, in the Piedmontese army while encamped at a high elevation on the Mount Cenis and Little St. Bernard passes.[18]

From very early times both hemeralopia and nyctalopia have been attributed to "redundancy of humors in the system." Celsus repeats in connection with night-blindness[19] the observation made by Hippocrates regarding nyctalopia,[20] that it does not occur in women whose menses are regular. De Sauvages lays stress on the exposure incident to guard-mounting by day and night in a humid and nebulous atmosphere.[21] Demours particularly mentions exposure to the night air.[22] Hemeralopia is called moon-blindness by sailors, and is attributed by them to a morbific influence emanating from that planet, especially affecting such persons as commit the imprudence of sleeping on deck. In Brazil it has been described as endemic among the negroes;[23] it has also been said to affect especially persons with darkly pigmented eyes,[24] an observation which was made by Aristotle in connection with nyctalopia.[25] Stellwag observed numerous cases of night-blindness occurring in an asylum in Vienna, but almost exclusively in two pavilions which were exposed to the light on three sides,[26] and he cites this instance in support of the opinion that sleeping with the face turned toward the window may be an exciting cause of the affection. On shipboard it is often associated with scurvy, and the same connection was observed in the war in the Crimea.[27] In certain epidemics pregnant women have been especially affected.[28] As a rule, whether in epidemics of night-blindness or in the conditions prevailing in localities in which it has been observed as endemic at certain seasons of the year, also in most of the sporadic cases which have been reported, two principal factors are to be distinguished, namely, impaired nutrition and long-continued exposure to strong sunlight, often intensified by reflection from large bodies of water, snow, or sand; and it appears most rational to regard the former as a predisposing, and the latter as the chief exciting, cause of the affection. Simulation has doubtless often played a part in swelling the number of supposed cases in outbreaks which have occurred in garrisons, on ships, in workhouses, etc., and this probability must be considered in judging of some of the remarkably prompt cures which have followed very diverse plans of treatment.

Of the objective signs of hemeralopia, that upon which the most stress has been laid by military and naval surgeons is a considerable dilatation of the pupils, generally most conspicuous at night; also the sluggish response of the pupils to changes of illumination. Dryness of the scleral conjunctiva with formation of scaly patches, a dulled appearance of the corneal epithelium, even xerosis of the conjunctiva and cornea, also conjunctival hyperæmia with lachrymation and photophobia, a staring expression of the eyes, with the eyelids widely separated, have all been noticed, especially in endemic hemeralopia; but so far as organic changes have been remarked, they would seem to be connected rather with concomitant disturbances of nutrition than directly with the affection of vision.[29]

The duration of the affection in different cases, or as stated by different observers, has been variously reported as limited to a single day or to a few days, or as extending to several weeks or months. As a rule, recovery speedily follows any change which works an amelioration of the two conditions of impaired nutrition and undue exposure to strong light. Relapses are apt to occur on renewed exposure to conditions similar to those which have given rise to the first attack.[30]

The treatment of night-blindness, as also of day-blindness—in both of which conditions the name nyctalopia has been used with little or no discrimination—was, until well into the last century, chiefly depletive and derivative. Bleeding from the arm or from the angle of the eye,[31] cupping, purgation[32] by elaterium,[33] scammony,[34] etc.; the administration of emetics,[35] diuretics, and diaphoretics;[36] the application of blisters and other counter-irritants behind the ears[37] or to the back of the neck; errhines and masticatories;[38] baths, frictions, exercise, and gargles;[39] in extreme cases trepanning the skull;[40] various applications to the conjunctiva, especially of an ointment made from the juices exuding from roasting liver; also steaming the eyes with the vapor of water in which liver is boiling, to which is added the recommendation to eat the liver;[41] these are the therapeutic measures recommended by the earlier and later Greek and Roman authors, by the Arabian writers on medicine, and by their followers down to quite recent times. Seclusion from bright sunlight and amelioration of diet must have contributed incidentally to the cure, but upon these points little or no stress was laid. In modern times a short confinement to a more or less perfectly darkened room,[42] attention to any concomitant pathological conditions, improvement of the nutrition, and, above all, the removal of the patient from the sphere of operation of the combined causes of the affection, have taken the place of the heroic plans of treatment formerly in vogue.

Nyctalopia, in the sense of seeing exceptionally clearly in comparative darkness, has been observed in the case of prisoners confined for a considerable period in dark dungeons;[43] and such persons are said also to suffer from dazzling of the sight for a longer or shorter time after being set at liberty, or, in some instances, to have continued permanently day-blind.[44] Physiological or pathological variations in the size and in the dilatability of the pupils may be relatively favorable to night-seeing or to day-seeing, according as the pupils are habitually larger or smaller than normal. In ametropia—whether myopia, hypermetropia, or astigmatism—the requisite conditions for distinct vision are generally best in a strong light, owing to the incidental contraction of the pupils and the consequent partial suppression of disturbing circles of confusion on the retinæ; and this may be also the case in turbidity of the vitreous or in diffuse clouding of the crystalline lens, in which conditions the penetrating power of strong light may be required for fairly good vision. On the other hand, in certain cases of circumscribed central opacity of the cornea or crystalline lens, vision may be comparatively good when the pupils are widely dilated, as at night, and very bad when they are strongly contracted, as in bright sunlight. Normally pigmented eyes, as a rule, best fulfil the conditions for clear and undazzled vision in strong sunlight, whereas the sight of persons with very light blue eyes, and notably of albinos, is generally best in moderate light. Retinal irritation following prolonged exposure to direct or reflected sunlight (snow-blindness), and especially reflex irritability of the retina dependent on irritation of the terminal ramifications of the fifth nerve in the cornea and iris, are marked by excessive and often painful contraction of the pupils under the influence of strong light, with consequent inability to see well in the daytime (photophobia). It is a curious fact that nyctalopia (day-blindness) is mentioned by medical authors several centuries before the definite recognition of hemeralopia (night-blindness), and it is still more remarkable that the earlier teachings regarding the etiology and treatment, and also the name, of the former came later to be applied to the latter affection. Excluding cases of photophobia and of central opacity of the cornea or crystalline lens, the conditions to which the name nyctalopia is in any degree applicable are reduced to certain retinal affections attended with irritability, and to the few imperfectly reported instances of day-blindness following long confinement in the dark. A few brief notices exist of day-blindness of an endemic or epidemic type,[45] but no recent instance of the kind has been reported.

John Green.

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[1] Aetius, Paulus Ægineta, Oribasius, et al.

[2] Galen: Εἰσαγωγή, 16.

[3] Stellwag: Die Ophthalmologie vom naturwissenschaftlichen Standpunkte, Buch iv., § 193, Freiburg im Breisgau, 1853.

[4] *Vide* Himly: Die Krankheiten und Missbildungen des menschlichen Auges, Band ii., S. 451, Berlin, 1843.

[5] *Vide* Stellwag: *Op. cit.*, iv., § 197.

[6] *Ibid.*, iv., § 193.

[7] *Vide* Leber: Graefe-Saemisch, Handbuch der gesammten Augenheilkunde, Band v., cap. viii., § 380, Leipzig, 1877.

[8] *Ibid.*, cf. Demours: Traité des Maladies des Yeux, t. i., p. 424, Paris, 1818.

[9] Stellwag: *Op. cit.*, iv., § 197.

[10] Förster: Ueber Hemeralopie, etc. C. Raymond: Giorn. d'Oft. ital., xii.; *ibid.*, xx.; Ann. di Ott., ii. (cited from Leber: *Op. cit.*).

[11] Förster: *Ibid.*

[12] Leber: *Op. cit.*

[13] Carron du Villards: Guide pratique pour l'Etude et le Traitement des Maladies des Yeux, t. ii., Paris, 1838.

[14] Leber: *Op. cit.*, § 89.

[15] De Sauvages: Nosologia Methodica, cl. vi., ord. i., iii., i., Amstelodami, 1768.

[16] *Vide* Himly: *Op. cit.*, ii., S. 453.

[17] Blessig, *vide* Leber: *Op. cit.*, §§ 384, 385.

[18] Carron du Villards: *Op. cit.*, t. ii., p. 487 sq.

[19] Celsus: De Medicina, vi., vi., 38.

[20] Hippocrates: Προῤῥητικόν, B′.

[21] De Sauvages: *Loc. cit.*

[22] Demours: *Op. cit.*, i., p. 425.

[23] *Vide* Leber: *Op. cit.*, § 385.

[24] Dubois (cited from Schmidt-Rimpler in Eulenburg's Real-Encyclopädie der gesammten Heilkunde, B. vi., Art. Hemeralopie).

[25] Aristotle: Περὶ ζῴων γενέσεος, E′., ed. Bekker, p. 170, 16, Berolini, 1831.

[26] Stellwag: *Op. cit.*, iv., § 198.

[27] Ophthalmic Hospital Reports, ii., pp. 35–43, London, July, 1859.

[28] *Vide* Mackenzie: A Practical Treatise on the Diseases of the Eye, xxiv., xii., fourth edition, London, 1854.

[29] *Ibid.* Cf. Leber: *Op. cit.*, § 386.

[30] *Vide* Himly: *Op. cit.*, ii., S. 452.

[31] Paulus Ægineta, iii., xxii.

[32] De Sauvages: *Loc. cit.*

[33] Hippocratic Treatise, Περὶ ὤψιος.

[34] Paulus Ægineta: *Loc. cit.*

[35] Demours: *Op. cit.*, p. 430.

[36] De Sauvages: *Loc. cit.*

[37] *Ibid.*

[38] Paulus Ægineta: *Loc. cit.*

[39] Celsus: *Loc. cit.*

[40] Hippocratic Treatise, Περι ὤψιος.

[41] *Ibid.* Celsus: *Loc. cit.* Paulus Ægineta: *Loc. cit.*, et al. Said to be even now a popular remedy in Italy and in other European countries, and still occasionally lauded by medical writers. Cod-liver oil has also been recommended as of especial therapeutic value.

[42] Netter (cited from Leber, *op. cit.*, § 386).

[43] Buffon, *vide* Himly: *Op. cit.*, ii., S. 449, note.

[44] *Vide* Larrey: Mémoires de Chirurgie Militaire et Campagnes.

[45] *Vide* Mackenzie: *Op. cit.*, xxiv., xiii.

HEMIANOPSIA is a condition of blindness limited to one-half of the visual field. *Hemiopia* is used as a synonym incorrectly, as it signifies vision (not blindness) in one-half of the visual field. This condition may be present in either the outer (temporal) or inner (nasal) half of the field of vision, and may affect one eye alone or both eyes. If both eyes are affected like-named halves of both may be involved—*e.g.*, the left half of both eyes, in which case the condition is called *homonymous hemianopsia;* or unlike-named halves of both eyes may be involved—*e.g.*, the left half of the left eye and the right half of the right eye, in which case the condition is known as *heteronymous hemianopsia.*

By means of Förster's perimeter the visual field of each eye has been determined (Fig. 2597). It is found to have an irregular outline, and to be divided into a large outer and a small inner portion by a line drawn vertically

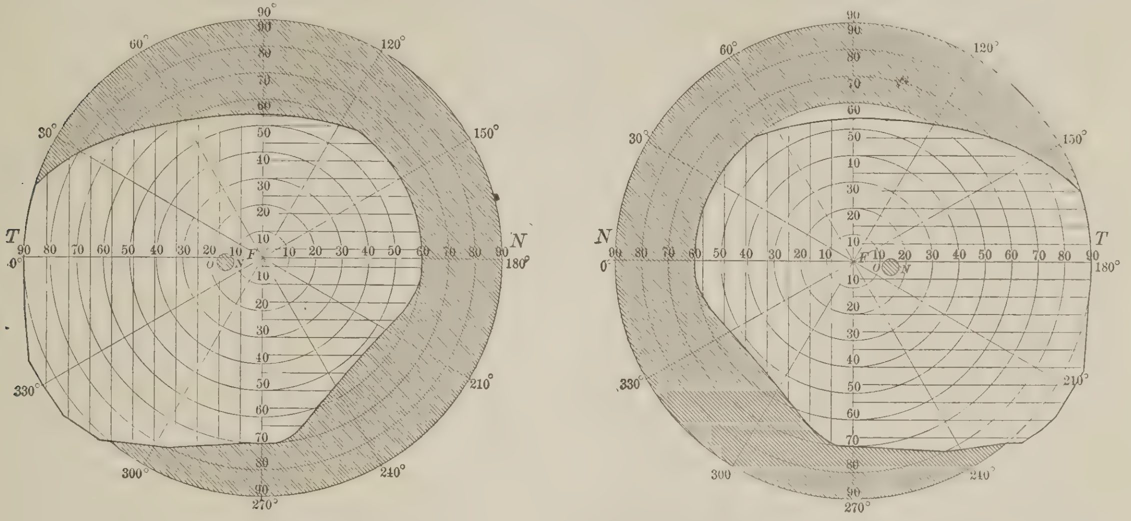

FIG. 2597.—Visual Field of Both Eyes, taken separately. The vertical lines represent the portion of the visual fields affected in left hemianopsia; the horizontal lines, in right hemianopsia.

through the point of fixation. This point corresponds with the macula lutea, and lies on the outer side of the entrance of the optic nerve. The two inner fields really overlap one another, so that the actual outline of the entire visual field of both eyes is that represented in Fig. 2598. It becomes evident from this figure that the loss of one nasal half of the visual field is not appreciated by any one unless the unaffected eye is closed. This fact is of importance, as it is evident that a nasal hemianopsia is a symptom which may not be noticed by a patient, and hence must be looked for by the physician. The unequal size of the two portions of each visual field is so marked that in an homonymous hemianopsia the patient usually ascribes the blindness wholly to a defect in the eye whose larger portion is affected, and a careful medical examination is necessary to establish the existence of a bilateral affection.

To determine a patient's visual field, each eye is to be tested separately. The patient holds a card before one eye and looks the examiner in the eye with the other. Any object, preferably a white one, is then moved about in the visual field of the eye which is uncovered, and the power and extent of indirect vision is thus determined. If hemianopsia exists the patient will be unable to see the object when it is within the field of vision which is defective, or when it is carried beyond the vertical line passing through the fixation point toward the defective side. More accurate measurements may be made by means of a perimeter, but the method described is sufficient to establish the existence of blindness in one-half of the visual field. In no case of hemianopsia is direct vision at the fixation point affected.

Since the lens of the eye reverses the image of the object seen upon the retina, each half of the visual field corresponds to the opposite half of the retinal expansion. A hemianopsia therefore indicates a suspension of function in the half of the retina opposite to the defective visual field. Such a functional derangement of one-half of the retina is rendered possible by the origin, course, and distribution of the nerve fibres in the optic nerves, as seen in Fig. 2599. Each optic nerve is seen to pass from the eyeball back to the optic chiasm, and there to divide into two parts. One of these turns outward and joins the optic tract of the same side. The other crosses the median line in the chiasm, decussating with its fellow from the opposite optic nerve, and joins the optic tract of the opposite side.

The anatomical separation of the fibres from one optic nerve renders it possible for a lesion situated in the chiasm, or in the optic tract, to affect a portion of the fibres coming from one eye, and consequently a part of the retina; while a lesion affecting the optic nerve itself involves necessarily the entire extent of the retina, producing amaurosis, not hemianopsia. It is found that the portion of the retina lying to the outer side of the fixation point is joined with the fibres of the optic nerve which pass directly into the optic tract of the same side; while the inner portion of the retina sends its fibres across the median line in the decussation (Fig. 2599). It has been already shown that the nasal portion of the retinal expansion, corresponding to the temporal half of the visual field, is larger than the other portion. The number of fibres in the optic nerve which decussate is greater than the number which do not cross the median line. The ratio of non-decussating to decussating fibres in the optic nerve, in any animal, is directly proportionate to the extent of the visual field common to both eyes. Thus in the horse, or the rabbit, in whom there is no part of the visual field which is common to both eyes, the decussa-

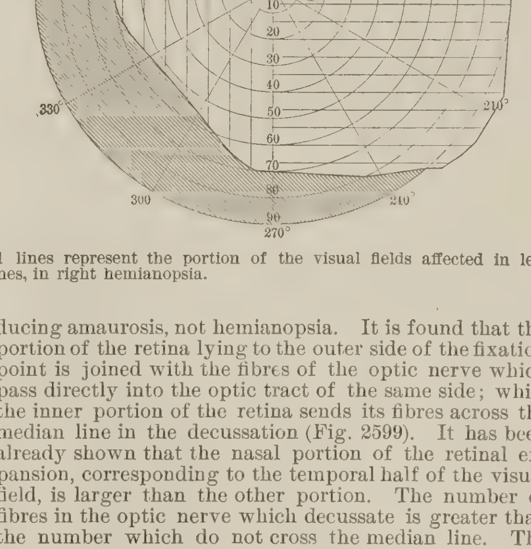

FIG. 2598.—Outline of the Entire Visual Field of Both Eyes.

tion of the optic fibres is total. In dogs, cats, monkeys, and man, in whom, to a less or greater degree, the eyes are directed in parallel lines, the decussation is partial. In a rabbit or horse hemianopsia is impossible. In the other animals named it is observed.

Unilateral hemianopsia is produced by lesions affecting the optic chiasm only. If the lesion lies on the outer side of the chiasm it produces nasal hemianopsia on the side of the lesion. Thus a tumor pressing upon point *N* in Fig. 2599 would produce blindness in the temporal half of the left retina, and hence nasal hemianopsia in the left visual field. If the tumor lies in front of or behind the chiasm, or presses upon it from above or below in such a manner as to involve the decussating strand of fibres either before or after they have crossed to the opposite side, it will cause a temporal hemianopsia (*T* in Fig. 2599). As it is impossible to determine whether the fibres are affected before or after decussation, no statement as to the side upon which the lesion lies can be made.

Bilateral hemianopsia is far more common than unilateral. It may be of several varieties. Bilateral nasal hemianopsia implies a destruction of the direct optic fibres on both sides, the decussating fibres being unaffected. Such a case has been observed by Knapp, in which a tumor surrounded the chiasm, pressing upon its sides, but not affecting its centre. Bilateral temporal hemianopsia is a rare condition, and is produced only by a lesion which divides the chiasm through its antero-posterior diameter without affecting its lateral halves, thus destroying both decussating strands. It has been observed in a few cases of tumor of the hypophysis.

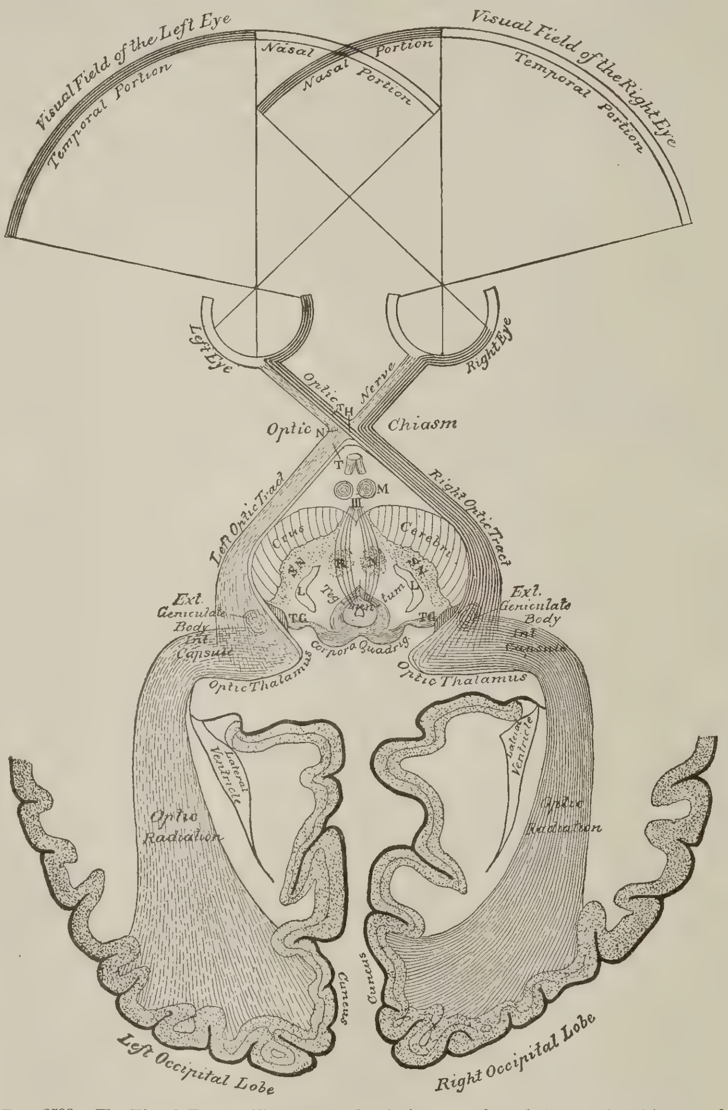

FIG. 2599.—The Visual Tract. The result of a lesion anywhere between the chiasm and cuneus is to cause homonymous hemianopsia. III. Third nerve; S. N., substantia nigra; R. N., red nucleus of tegmentum; L., lemniscus; T. G., fibres from optic tract to corpora quadrigemina.

Bilateral homonymous hemianopsia is a not uncommon condition, and may be produced by many causes, and by lesions situated in many various parts. This will be better understood after the course of the optic tracts has been followed to their terminations in the visual area of the cerebral cortex (Fig. 2599), since a lesion at any point in this course will produce the symptom named. Each optic tract, after leaving the chiasm, passes around the crus cerebri, lying directly upon the fibres which pass through the foot of the crus (pes pedunculi), and ends on the level of the tegmentum of the crus in the external geniculate body, in the pulvinar of the optic thalamus (*i.e.*, the eminence forming its posterior surface), and in the corpora quadrigemina anteriora, which latter it reaches by the brachium conjunctivum. The last-named fibres of the optic tract have probably nothing to do with conscious vision, and may therefore be excluded from consideration in studying hemianopsia. They form the sensory part of a reflex arc, whose motor part is made up of the motor nerves to the eyeballs. The functions of this reflex mechanism are to direct the motion of the eyeballs, and to regulate the process of accommodation and the size of the pupil. The primary visual centres are, therefore, the external geniculate body and optic thalamus. The fibres of the optic tract end in the cells of these ganglia, and from these cells new fibres arise which collect in a large tract and issue from the posterior external angle of the optic thalamus into the posterior third of the internal capsule. This visual tract turns upward and backward in the internal capsule, radiates into the centrum semi-ovale of the occipital lobe, and, passing around the outer border of the posterior horn of the lateral ventricle, terminates in the convolutions of the occipital cortex, including the cuneus. At no point in this course is any decussation found. The only decussation of fibres between the eye and the cortex is in the optic chiasm.[1]

Bilateral homonymous hemianopsia may be caused by a destructive lesion lying anywhere in the course of these fibres between the optic chiasm and the occipital cortex, or by a lesion in the cortex which destroys the perceptive centres in which the fibres end. Wherever the lesion, the character of the symptom will be the same. From the accompanying symptoms, it is in some cases possible to locate the lesion causing the hemianopsia. Thus, if the optic tract is involved as it curves around the crus cerebri, the same lesion which causes the hemianopsia will be likely to affect the motor tract in its passage through the pes, or to involve the third nerve in its exit from the pes. In this case hemianopsia and hemiplegia of one side, with oculo-motor paralysis of the other side, will be combined. Or, if the termination of the optic tract in the geniculate body and thalamus is involved the lesion, unless extremely limited, will affect the sensory tract from the opposite side of the body in its passage through the tegmentum of the crus, or in the posterior portion of the internal capsule; and in this case hemianæsthesia and hemiataxia will be associated with hemianopsia. Or, if the visual tract in its passage through the internal capsule is involved by disease in the basal ganglia or in the capsule, the proximity of both sensory and motor tracts in the capsule will render a combination of hemianopsia, hemianæsthesia, and hemiplegia quite probable. This is the seat of the lesion, and this is the combination of symptoms most frequently observed (see *Brain Diseases: Diagnosis of Local Lesions*).

Lesions in the centrum ovale involving the optic radiation may not produce any other symptom than that under discussion. If it is the left hemisphere, however, in which the disease is present, a condition of word-blindness (see *Aphasia*) is not infrequently associated with it; and in all the cases of word-blindness hitherto reported hemianopsia has been found. This is probably due to the destruction of association fibres between the occipital and temporal lobes which lie side by side with the visual tract.

Lesions in the cortex of the occipital lobe produce no other symptom than hemianopsia. It is impossible to limit the visual area of the brain to any one part of the lobe, since destruction of a portion of the convexity has produced the same result as destruction of its median surface.[2] Nor is it possible to project upon the cortex the retinal expansion, as has been attempted by Munk, since lesions in all parts of the occipital convolutions produce the same effect.

Lesions in the angular gyrus may produce hemianopsia, and it is well known that Ferrier has located in this convolution the visual centres. It is probable that such lesions have caused the symptom by affecting the visual tract as it passes beneath this gyrus in the centrum ovale. There is no reliable evidence that a unilateral lesion in the cortex can produce blindness of one eye alone.

Hemianopsia is, therefore, a local symptom of brain disease of great value in determining the situation of a lesion, when considered in connection with other symptoms. The symptom alone affords little evidence of the nature of the disease producing it, since it may be caused by any of the various forms of brain lesion (see *Brain*). It has been observed in cases of basilar meningitis, in tumors of the occipital lobe and basal ganglia, in hemorrhage and softening involving the internal capsule, and in embolism of the terminal branches of the posterior cerebral artery, and of the trunk and posterior branch of the middle cerebral artery, as well as in other rarer conditions.

The diagnosis of the symptom may be made by an examination such as has been described. The prognosis and treatment of it will depend entirely upon the nature of the disease producing it. *M. Allen Starr.*

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[1] Von Monakow: Arch. f. Psychiatrie, xiv., 698–750; xvi., 151–200. Wernicke: Lehrbuch der Gehirnkrankheiten, Bd. i., S. 79–84.

[2] Compare cases of Haab with those of Fritsch and Westphal cited by Starr: Visual Area of the Brain, American Journal of the Medical Sciences, January, 1884; and these with Seguin's case, Journal of Mental and Nervous Disease, January, 1886. Full bibliographies are to be found in these articles.

HEMICRANIN is a mixture of phenacetin five parts, and one part each of caffeine and citric acid.

W. A. Bastedo.

HEMIDESMUS.—Hemidesmus Radix. *Indian Sarsaparilla.* "The dried root of *Hemidesmus indicus* R. Br." (B. P.) (Fam. *Asclepiadaceæ*). The plant is a slender, twining shrub, native of India. The description in the British Pharmacopœia, into which it is introduced apparently out of compliment to the Indian physicians, is as follows: "The root is long, rigid, nearly cylindrical, tortuous and longitudinally furrowed. It seldom exceeds ¼ of an inch (6 mm.) in thickness and is of a reddish-brown or dark-brown color. On one side of the root the cork is frequently separated from and raised above the cortex, and is transversely fissured. The transverse section exhibits numerous laticiferous cells in the cortex. The root has a fragrant odor and a somewhat sweet taste." A syrup, made from one ounce of hemidesmus to ten and one-half ounces of menstruum, is used in England.

The medicinal properties of hemidesmus are said to be those of sarsaparilla, in the stead of which it is used in British India; in Europe or in this country it is rarely used. Its composition has not been fairly studied, but it is safe to say that nothing physiologically very peculiar or active is contained in it. An odorous principle, perhaps cumarin, has been partially examined. The syrup in which it is prepared, like that of sarsaparilla, is scarcely more than a flavoring vehicle. *Henry H. Rusby.*

HEMIPLEGIA (*ἥμισυς*, "the half," and *πλήσσω*, "I strike"). Paralysis of one-half of the body.

Causes.—Hemiplegia, as ordinarily seen, is usually the final result of an apoplectic stroke, from cerebral hemorrhage, embolism, or thrombosis. The stroke is often attended by loss of consciousness and profound paralysis, but if the patient live the paralysis gradually lessens and leaves the final hemiplegic state. In some instances the paralysis is not ushered in in such stormy manner, but increases gradually for a day or two, either with or without loss of consciousness. The early symptoms are the expression of shock to a larger or smaller part of the brain, of pressure, and, sometimes, of inflammation of the tissues adjacent to the lesion, as well as of destruction of brain substance. The final symptoms are the expression of destruction and degeneration of brain tissue.

Hemiplegia may also come on slowly, caused by a brain tumor, brain abscess, chronic softening, meningitis, etc. In these instances the clinical picture may be complicated by a sudden paralysis from hemorrhage or thrombosis in the diseased area, or the like.

What has already been spoken of is organic hemiplegia, due to destruction or injury of the motor centres, or the cortico-muscular tract, that is, the tract of fibres carrying impulses from the motor centres to the muscles. But hemiplegia also occurs without palpable lesion. Notably this is true of hysterical hemiplegia.

Manifestations.—The paralytic manifestations are variable. Shortly after an apoplectic attack, if it be severe, most of the muscles on one side of the body are paralyzed. The arm and leg are entirely powerless. The muscles supplied by the lower branches of the seventh nerve, those of the cheek and mouth, are completely paralyzed. That side of the face is expressionless, and the mouth may be drawn toward the other side. But the muscles supplied by the upper branches of the seventh nerve—the orbicularis palpebrarum, occipito-frontalis, and corrugator supercilii—are as a rule but little affected. The tongue may remain motionless in the floor of the mouth. When protruded it deflects to the paralzyed side. The muscles of the chest are usually somewhat affected, and the breathing is less deep on the paralyzed side. The writer has found the latter symptom an aid to diagnosis of both the presence and the side of hemiplegia in cases in which the coma was so profound that it was impossible to elicit any sign of power on either side. On the other hand, some muscles almost invariably escape injury. These are the muscles supplied by the third, fourth, fifth, and sixth nerves—those of the eyeballs and of mastication—and the muscles concerned in swallowing and vocalization. The articulation is usually somewhat indistinct for a short period, or there is a loss of speech—aphasia. Aphasia occurs mostly with right hemiplegia (in right-handed individuals). But even indistinctness of speech, when there is no aphasia, is often more marked in right than in left hemiplegia.

The high degree of paralysis just described, though in rare instances it remains permanently, is usually of short duration. The paralysis of the muscles of the trunk and of the tongue, and the indistinctness of articulation usually disappear at an early period. The facial paralysis also diminishes, sometimes disappears altogether. The paralysis of the arm is usually most profound, and slowest to improve.

The hemiplegia of a later period is, as a rule, to be found only in the face and extremities, though sometimes the tongue continues, when protruded, to deflect toward the paralyzed side. If the facial paralysis be slight, it will be observed that the nasolabial fold is less marked than on the sound side, that the upper lip is less arched, and the angle of the mouth droops somewhat on the affected side. A slight paralysis becomes more marked when the muscles are actively exercised, as in smiling, exposing the teeth, etc. Not rarely the effort to expose the teeth will reveal a decided facial paralysis, while laughing will show none whatsoever—probably a psychic reflex act on the part of the thalamus. The opposite, the appearance of a more decided paralysis with laughter than with voluntary movements of the face, is observed in rare instances, probably indicating lesion of the thalamus. In the extremities usually certain groups of muscles are most likely to be paralyzed, or most deeply affected, *e.g.*, extensors of the fingers, supinators, trapezius muscles, anterior tibial, and peroneal group of muscles, and flexors of the knees. As a rule the hands and feet are more affected than the higher parts of the extremities. The skilled movements of the fingers are most affected. In walking a dragging of the toes on the paralyzed side is often observed.

In cases of permanent hemiplegia, especially if the paralysis be considerable, after a few weeks contracture of the paralyzed muscles usually occurs, a condition termed late rigidity. In a well-marked case we shall find the arm drawn toward the chest, the forearm flexed on the arm and pronated, and the fingers flexed; in the inferior extremity all the joints extended, and the foot in the position of talipes equino-varus. The rigidity is usually greater in the upper than in the lower extremity. In rare instances we find extension of the joints of the arm instead of flexion, or flexion in the lower extremity instead of extension. Sometimes the muscles of the face are also affected; then the naso-labial fold becomes deeper, and the angle of the mouth elevated on the affected side. In extreme cases the rigidity is more or less constant; but usually it is much less than in the instance above described, and it is then increased by voluntary efforts to move the parts, or by emotional excitement, while it is diminished or absent during sleep. In some cases the rigidity improves very much with time, so that it is only observable during acts requiring special skill.

Hemiplegics often succeed in walking with the aid of a cane, even though the leg be completely paralyzed, especially if the limb be at the same time rigidly extended. In this case the pelvis and hip of the paralyzed side are elevated by the contraction of the abductor muscles of the thigh on the sound side, and the foot is then propelled forward by the action of the inward rotators of the healthy limb, the toes usually scraping the floor during the forward movement. The body now rests partly upon the foot of the paralyzed limb, partly on the cane, held in the hand of the sound side, the centre of gravity being between them while the healthy limb is being brought forward.

In permanent hemiplegia the deep reflexes are usually very much increased. The knee jerk, elbow jerk, wrist jerk, etc., are exaggerated and the ankle clonus can be elicited, which is almost never found in healthy individuals. The deep reflexes may even be exaggerated, though to a less degree, on the non-paralyzed side. But it is also true that the latter side may be weaker than before the paralysis set in. There is often some alteration in the condition of the superficial reflexes. Only one of the latter has much diagnostic import, the toe phenomenon, recently described by Babinsky. The usual plantar reflex is flexion of the toes. Babinsky observed that when there is disease of the pyramidal tracts stroking the sole of the foot produces extension of the big toe. Care is usually necessary to get the proper response. The patient's mind should be distracted if possible, and then a stroke slowly made from the heel toward the toes. A not pointed pencil answers very well for making the stroke. This sign has not the full significance of the ankle clonus, because not so commonly found, yet it may have a greater diagnostic value, because it may be found very soon after the paralysis sets in, while one or several weeks elapse before the ankle clonus can be elicited. In several instances the writer has found the toe phenomenon within one, or at least a few, hours after the onset of an apoplectic stroke.

Other motor phenomena are observed more or less frequently, the probable results of irritation of, or lessened inhibition in, the motor areas. Often there is a movement of the paralyzed arm—hand lifted to the head or the like—in yawning, etc. A slighter movement in the paralyzed extremity is frequently observed at the same time with corresponding movements of the sound limb. The opposite is also observed, viz., contractions of corresponding muscles on the sound side with attempted movements of the paralyzed side. The kind of motor phenomena just described are usually spoken of as accessory movements. More rarely tremor, or choreic movements, or athetoid movements (slow continuous movements of fingers and toes) are found in the paralyzed extremities. The choreic and athetoid movements have been supposed to occur especially with lesion of the thalamus. If that be true, it is probable that it is rather because the posterior part of the internal capsule is affected than because of injury to the thalamus itself.

SEAT OF LESION.—Hemiplegia is most frequently caused by a lesion of the corpus striatum, or in its neighborhood, the paralysis being on the opposite side of the body. If the paralysis be permanent, it is because the internal capsule has been damaged, while the late rigidity is attendant on degeneration of the pyramidal tracts.

Hemiplegia, produced by lesions in other parts of the motor tracts, has in some instances special manifestations.

Cortex.—Lesions in the motor area of the cortex, the anterior and posterior central convolutions, more frequently produce monoplegia—paralysis of one limb, or of the face—than hemiplegia, but the latter may occur if the lesion be sufficiently extensive. Such lesions are often attended by convulsive movements, especially in case of a neoplasm. In such instances there occur usually periodic attacks of clonic spasms in one extremity or one side of the face; in the hand if the lesion chiefly affect its centre, etc. These spasms are likely to be at first quite limited and not accompanied by loss of consciousness. But in succeeding attacks the convulsions may extend to other parts of the body. They first travel over one side of the body. If the convulsion also seizes the other side, loss of consciousness is likely to supervene. There is often some blunting of the sensibility corresponding to the amount of paralysis, indicating that the cortical centres for motion have also direct relationship with the sensory functions. But such cases do not always give a like clinical picture. In a case of the writer's, in which there was a large tumor on the convexity, implicating chiefly the leg centre, there was paresis of the opposite arm and leg, but no appreciable impairment of sensation, and there had never been any convulsive movement.

Crus Cerebri.—Hemiplegia from lesion of the crus cerebri is often attended by paralysis of the third nerve on the side of the lesion. There is paralysis of the face and extremities on one side, and of the muscles of the eye on the other side.

Pons Varolii.—Lesions of the pons Varolii cause what has been termed alternate hemiplegia, that is, paralysis of the arm and leg on one side, and of the face on the other, the extremities being affected on the side opposite to, the face on the same side as, the lesion. The reason for this is the following: The central prolongation of the seventh nerve, like that of all other motor nerves, passes from one side of the brain to the other, the site of crossing being, in case of the seventh, in the pons. Lesions, then, in the latter locality may affect only the peripheral parts of the nerve—the nerve trunk itself, or its nucleus—and the facial paralysis be on the side of the lesion. The facial paralysis in such cases differs from that with ordinary hemiplegia, in that it has the stamp of peripheral paralysis. The paralysis is likely to be complete, all parts supplied by the nerve being equally affected, the eyelids and forehead as much as the lips and cheek. There will also be found changes in the electrical reactions, the so-called reaction of degeneration. The electrical reactions of the nerve and faradic contractility of the muscles are lost, while the galvanic contractility of the muscles may be heightened, but with a change in the normal formula of the reactions. Such changes in the electrical reaction are never found in central paralysis, only in paralysis of a peripheral type. If the degree of paralysis be great, some atrophy of the facial muscles may also take place.

Medulla Oblongata.—Hemiplegia from lesions of the medulla is likely to be attended by paralysis of other cranial nerves, while the seventh nerve escapes. There are likely to be a considerable paralysis of the tongue, indistinctness of articulation, and paralysis of the vocal cords from the involvement of the hypoglossal and pneumogastric nerves. The writer had under his observation a case of unusual interest, in which there was probably a lesion of the medulla and pons of traumatic origin. The injury was caused by an iron rod penetrating the right submaxillary space, and passing upward four inches in the direction of the foramen magnum. Immediately after the injury there was complete paralysis of the right arm and leg, of the cheeks, lips, tongue, and vocal cords. The patient was unable to swallow or to make any vocal sound. The upper part of the face was unaffected. He could move the eyes freely, open and close the lids, and was entirely conscious. There was also loss of sensation on the left side of the face. The condition of the patient rapidly improved, but there remained permanently a right-sided paralysis, considerable difficulty in articulation, and anæsthesia of the left side of the face.

Spinal Cord.—Hemiplegia from unilateral lesion of the cord is not attended by paralysis of any cranial nerve, but the arm and leg of the same side are paralyzed if the lesion be in the cervical region, and the leg only, if the lesion be at a lower level. Such a unilateral lesion produces a peculiar array of symptoms, spoken of as Brown-Séquard paralysis, because produced experimentally and first described by that distinguished physician. The symptoms are motor paralysis and loss of muscular sense, on the side of the lesion, in every part below it, and impaired or lost tactile, pain, and temperature sense on the opposite side. There is likely to be a narrow area, encircling the body, at the level of the lesion, in which there is hyperæsthesia. The explanation of the symptoms appears to be that the tracts for the motor fibres and muscular sense run up in the cord on the same side as are the corresponding nerve roots, and only cross to the other side in the medulla, while the tracts for tactile, pain, and temperature sense cross to the other side of the cord immediately after leaving the nerve roots.

Infantile Paralysis.—Some cases of hemiplegia of infancy, which are either congenital or acquired early in life, deserve special mention. The lesion is a varied one, from hemorrhage, inflammation, arrested development, etc., and is often of traumatic origin. The hemiplegia is usually attended by contractures of the paralyzed muscles, and by a considerable arrest of development. The leg and arm are smaller in circumference and shorter than those on the sound side, and the face is also frequently smaller than on the paralyzed side. The choreic, athetotic, and accessory movements already spoken of occur very frequently in these cases. Great impairment of intellect, even complete idiocy, is frequently found, and epileptic convulsions become established in many cases.

Hysterical Hemiplegia.—In hysterical hemiplegia the paralysis is mostly confined to the extremities, the face escaping. When there is an appearance of facial paralysis it is usually found that there is really spasm, not paralysis of the facial muscles. It is not so commonly true of hysterical as of organic paralysis that the arm is more profoundly paralyzed than the leg. Mostly the paralysis is not complete. There is paresis, rather than paralysis. In that case one frequently observes that the resistance of the patient to the efforts of the examiner to move the limb is done in a jerky manner. There is resistance for a moment, then none whatever, as though there were no effort on the part of the patient. More power may be manifested in emotional conditions, in gesticulation, etc. A degree of power may be revealed in an apparently paralyzed limb, by a sense of resistance on passively moving the limb, or by the limb remaining momentarily in the position in which it has been placed, a position requiring some muscular effort. The gait is ordinarily different from that of organic hemiplegia, the paralyzed foot rather dragging behind, than swinging forward in a circle.

The reflexes are commonly not affected, neither the superficial nor deep being altered in the way already described as occurring in organic hemiplegia. Not rarely contractures occur in the paralyzed limbs. As a rule they make the prognosis less favorable, at least in so far as the duration of the symptoms is likely to be much greater. Anæsthesia is commonly found with hysterical hemiplegia. The sensory symptoms are usually more extensive than is the paralysis, the face being affected as well as the extremities. There may be both superficial and deep anæsthesia and also of the special senses on the affected side. Not rarely there is partial anæsthesia, loss only of tactile, or only of pain sensation, or impairment of one more than of the other. The patient may be altogether unaware of the impaired sensation.

Hysterical hemiplegia affects mostly the left side. It has been said to occur three times as often on the left as on the right side. It may come on abruptly or gradually. Not rarely it follows a convulsive seizure. It may be caused by an injury, or any physical or mental shock. Very likely an emotional condition, or, at least, some mental impression underlies the hemiplegia in most instances, though it need not immediately follow upon the exciting cause.

The patient usually recovers from the paralysis, but it may take days or years. During this time the paralysis may remain unchanged, or it may vary greatly in its intensity. The disappearance of the paralysis, just as its inception, may be due to mental causes, shock, suggestion, or the like.

The characteristics of the paralysis just given may suggest or establish the diagnosis of hysteria. But it is well to remember the ofttime difficulties of diagnosis, not the less so that not rarely there is association of hysteria and organic disease. Where the question of hysteria has arisen mistakes have been made not infrequently even by the best men. Not only the peculiarities of the supposed hysterical symptoms should be considered, but also the personality of the patient, the apparent cause of the manifestations, as well as the history and the whole clinical picture. *Philip Zenner.*

HEMORRHAGE.—From αἷμα, blood, and ῥήγνυμι, to break through. The blood may escape from the arteries, veins, or capillaries, and from its origin the hemorrhage is designated arterial, venous, or capillary.

In arterial hemorrhage the blood escapes from the arteries in jets synchronously with the contraction of the left ventricle, and flows continuously during diastole. The blood is then of a bright or pale red according to the quality.

In venous hemorrhage the blood escapes from the veins in a continuous stream, and is dark in color. Blood has been seen to escape from a hemorrhoidal vein in jets, but synchronously with the contraction of the abdominal muscles. In capillary hemorrhage the blood oozes from the capillaries over a smaller or larger surface, and is reddish in color.

Secondary hemorrhage is bleeding that arises from failure in repair of an injured or ligated vessel or from ulceration into a vessel (Gould). The cause may be in the altered composition of the blood itself or in a rupture of the vessels, or both conditions may obtain at one and the same time. Sometimes abnormal pressure may cause the rupture of thin-walled veins, as happens, for example, in rupture of the thin-walled veins of the lower end of the œsophagus in hepatic cirrhosis.

Just what are the alterations in the blood which favor hemorrhage are not definitely determined, but the white corpuscles are greatly increased in numbers and the time required for coagulation is increased. The coagulation time may be determined by the coagulometer; normal blood clots in the tubes in from three to five minutes. In some forms of purpura the coagulation time is retarded to ten or fifteen minutes, and in hæmophilia it has been delayed for as long a time as fifty minutes (Osler).

These changes in the constitution of the blood, which lessen its coagulability and thus favor hemorrhages, obtain particularly in leukæmia, purpura, and prolonged icterus, especially if associated with malignant disease.

Of recent years there has been an increasing tendency to regard the spontaneous hemorrhages occurring in newborn children as a manifestation of micro-organismal disease; and, although this view can scarcely as yet be said to be thoroughly established, there are a great many facts in favor of it (Thompson in "Allbutt's System").

Consequences.—Repeated small hemorrhages may gradually bring about a profound degree of anæmia. Large hemorrhages result in anæmia, but they are also followed by a condition of shock. It has been shown conclusively that death from hemorrhage takes place in consequence of a lowering of intracardiac and intravascular pressure, incompatible with the continuance of the function of the circulatory organs.

Hemorrhage may result disastrously, not only from the loss to the individual of a large quantity of blood, but also from the pressure of the escaped blood on adjacent structures. This is notably the case in intracranial and pericardial hemorrhages.

Symptoms.—The symptoms vary with the rate and quantity of blood lost. In repeated small hemorrhages anæmia is the obvious result. The objective signs are pallor of the skin and mucous membranes, coldness of the surface, the degree of anæmia present being most accurately determined by a blood count. It is of course evident that a much greater quantity of blood may be lost in small quantities and at intervals without a fatal result than in one or two large hemorrhages. In the former instance repair is constantly going on and the system acquires toleration.

The shock resulting from the rapid loss of a large quantity of blood is most alarming to all concerned. The patient becomes rapidly pale, cold, and restless. The dilated pupils, blurred vision, weak voice, small or imperceptible pulse, yawning, and the appeal for more air are evidences of the resulting acute anæmia. The patient may complain of roaring noises in the ears, a cold, clammy perspiration may cover the body, and the thermometer may not register at all in the axilla, and give a very low temperature per rectum.

At other times the evidences of hemorrhage are to be sought for in focal lesions of the brain or in the presence of physical signs of fluid in the pericardium, in the pleura, or in the abdomen.

It is not always easy to differentiate the symptoms of acute anæmia the result of a large concealed hemorrhage, from shock due to other causes. Reliance must be placed upon the history of the onset, and the exclusion of other causes of shock, such as fright, local injuries to important organs, extensive superficial burns, severe pain, and the presence of the physical signs of fluid in the great cavities of the body.

Treatment may be prophylactic, constitutional, and local.

Prophylaxis.—The researches of Dr. A. E. Wright have shown that the coagulability of the blood may be increased by the administration of salts of lime. Mayo Robson has made practical application of this discovery, and has found that the administration of thirty-grain doses of calcium chloride every four hours for a few days before operation has rendered the blood more plastic and has lessened the tendency to bleeding, both at the time of operation and subsequently. After the operation the drug may be continued by the mouth or by nutrient enema.

Before beginning an operation usually attended by considerable hemorrhage, some surgeons have made it a practice to introduce into the circulation through a vein or subcutaneously a litre of normal saline solution.

In operations upon an extremity much blood can be saved by previously placing around the limb an Esmarch elastic band. The constricting band should be two inches or more in width and so placed that important nerves shall not be unduly pressed upon. Negligence of this precaution has occasionally resulted in a more or less persistent paralysis of the parts below the elastic ligature. There is no object in applying this bandage too tightly. Sufficient pressure to arrest the circulation in the arteries is better than more. Before applying the Esmarch band the limb may be elevated for a few minutes. Force of gravity will materially lessen the quantity of blood in the vessels. It is not usually wise to bandage the limb before applying the constrictor; by so doing septic matter might be forced along the vessels into the circulation. Troublesome oozing is apt to follow the prolonged application of Esmarch's elastic band. It is due to a degree of vaso-motor paralysis.

Temporary ligation of vessels may be practised with safety. Senn states that a temporary ligature may be left on a vessel for twenty-four hours without permanent injury, provided the ligature is not drawn tight enough to injure the intima. He has frequently placed temporary ligatures on the carotid at the level of the lower border of the thyroid cartilage, before operating on the parts above. He refers especially to operations performed on the pharynx, parotid, and submaxillary regions. He places a double ligature, which if need be can be made permanent. Temporary may well replace preliminary ligature of large arteries in suitable cases.

Compression of the abdominal aorta as practised by Macewen is a valuable prophylactic measure when indicated.

Constitutional Measures.—Many drugs are held in high repute as hæmostatics. Mention may be made of aromatic sulphuric, tannic, and gallic acids, spirits of turpentine, ergot, acetate of lead, and opium. Some act by producing clotting, some by stimulating the vessels to contract, and opium by equalizing the circulation and thus lessening intravascular pressure at the bleeding point. Turpentine has many advocates. It may be given three or four times daily in doses of ten to fifteen minims. In hemorrhage from the intestinal mucous membrane opium has been found very useful.

Stypticin, hydrochloride of cotamin, is the base of the opium alkaloid narcotine. It is a yellow, inodorous, bitter powder. It is usually given in doses of three-fourths of a grain from five to eight times daily. In some cases three grains or even more may be safely given. A ten-per-cent. solution may be introduced in the form of deep intermuscular injections. It is said to have yielded good results (Senn).

Suprarenal capsule is now being used largely as a styptic. Its active principle is called adrenalin. Powdered suprarenal capsule may be used locally or may be given internally in doses of two or five grains. Adrenalin is very readily oxidized, and is on the market in solution. That prepared by Parke, Davis & Co., is adrenalin chloride 1 to 1,000 of normal saline solution. Its permanence is maintained by the addition of 0.5 per cent. of chloretone. It may be used locally or internally in doses of from five to thirty minims. Locally it acts in very weak solution. A solution made by adding one part of the 1 to

1,000 solution to one thousand parts of sterilized normal salt solution is an effective local astringent. Powdered suprarenal body and its active principle adrenalin act by causing the contraction of the walls of the vessel. Evidence of its effectiveness is accumulating daily. The writer has found it most satisfactory in arresting hemorrhage in epistaxis and in bleeding piles. As it acts by stimulating the contraction and closure of the gaping vessel, it might be expected to fail when applied to vessels whose surroundings prevented contraction, as, for instance, in the indurated base of a gastric ulcer or perhaps in hemorrhage from bone.

Local Treatment.—Arterial hemorrhage may be arrested spontaneously by the contraction of the vessel wall and the clotting of the blood. "If a small artery is completely divided the circular fibres of the muscular coat contract and narrow the orifice; at the same time the internal and middle coats curl up in the interior of the vessel, and the longitudinal fibres contract and shorten it, so that it retracts within its sheath. As a result, there is clotting of blood; as soon as the blood comes in contact with the tissues which are injured, or which are not similar to the lining membrane of the vessels, it undergoes coagulation. Consequently, as soon as the blood escapes from the vessel, clotting tends to take place, unless the escape of blood be so free that the clot is swept away by it. The clotting within the vessel extends up to the nearest collateral branch." Later on, the clot becomes organized into fibrous tissue. If the vessel is only partially divided it cannot contract within its sheath and the hemorrhage is more apt to continue. The spontaneous arrest of hemorrhage from veins and capillaries is due chiefly to clotting and sealing by lymph (Cheyne and Burghard).

Of all the artificial methods of arresting hemorrhage that by *ligature* is far and away the most important. The aseptic ligature is one of the great results of Lister's work. Of the absorbable ligatures catgut is the chief, and silk is the ideal non-absorbable ligature. Catgut may now be prepared in a manner that renders it aseptic and not too readily absorbed. It is certainly the best ligature to use in a field that is, or is likely to become, infected. Silk has the great advantage of being easily prepared and may be used in aseptic tissues. It is better to use the smallest sizes of both catgut and silk that can be used with safety. It is no longer thought necessary to tie a ligature tightly enough to rupture the intima. If the walls of the vessel are brought firmly in contact adhesions between them will take place and the vessel be quite safely occluded.

Suture of wounds in large arteries and veins may be successfully accomplished. Although Lambert, of Newcastle, successfully sutured a wound of the carotid artery in 1762, but little attention has been given to this method of closing wounds of blood-vessels until recent years. This method of closure should be adopted in wounds of important vessels, such as the aorta, carotid, axillary, or femoral arteries, when not more than half the circumference of the vessel is divided and when the wound is aseptic. Experiments seem to show that if end-to-end anastomosis is performed, after complete division of the artery, complete occlusion will occur in a few weeks, but not until sufficient time has elapsed for the collateral circulation to become established. The endothelial and connective-tissue proliferation which closes the wound in a part of the vessel wall goes on to complete occlusion when the whole circumference has been divided and afterward stimulated by many needle punctures and by the presence of the suture material. Closure of wounds of veins by means of sutures has also been practised successfully. In the suturing only the outer coats should be included, the intima being avoided. The sheath of the artery should also be sutured.

Pressure is a valuable means of controlling hemorrhage from small wounds and from veins. The hemorrhage from a ruptured varicose vein is thus readily stopped. Even bleeding from the sinuses of the brain may often be effectually arrested by pressure. In applying pressure it is important to get the pad directly on to the bleeding vessel. If this is at the bottom of a deep wound and it is not desirable to enlarge it, a graduated compress may be applied. Place first simply a small pad deep down on the bleeding point, then another against the first, and so on until sufficient pressure is obtained. In emergency cases, when bleeding is taking place from an extremity, a bandage or handkerchief or a pair of suspenders may be placed around the limb above the bleeding point. This may be tightened by twisting as in the Spanish windlass.

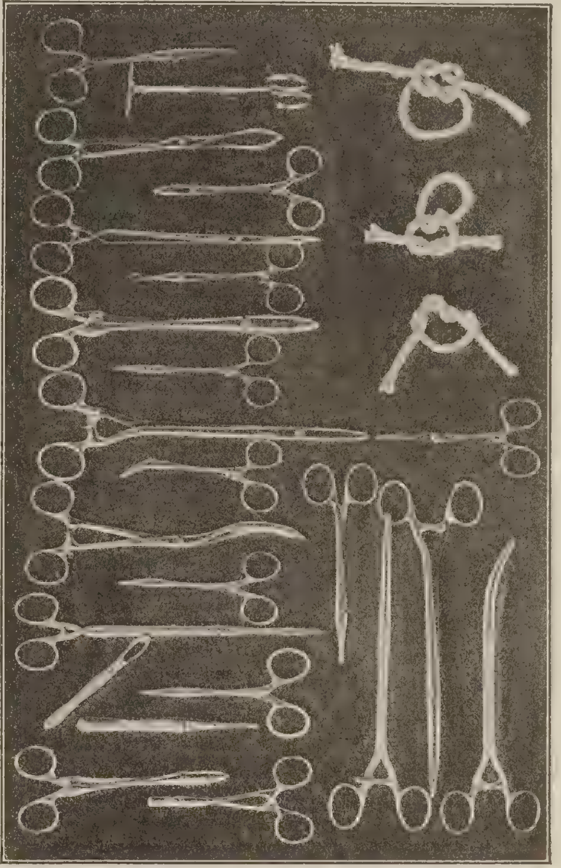

FIG. 2600.—Various Contrivances in Common Use for Arresting Hemorrhage. The three knots shown in the right-hand upper corner of the picture represent respectively (from above downward) the *surgeon's knot*, the *granny knot*, and the *reefer's knot*. Immediately below the last knot, placed transversely, is *Pean's artery forceps*; and below this are four different types of forceps known respectively (from left to right) as *Armstrong's forceps*, *Doyen's clamp forceps* (straight), *Terrier's clamp forceps* (curved), and *Richelot's clamp forceps* (lateral-curved). The left half of the picture is occupied by a series of eighteen different patterns of forceps known respectively (from above downward) as (1) *Kocher's forceps*, (2) *Pozzi's T-forceps*, (3) *Bottini's forceps*, (4) *Tait's forceps*, (5) *Pean's long light bleeding-point forceps*, (6) unnamed pattern of forceps, (7) *Greig Smith's heavy forceps*, (8) *Halsted's mosquito-point forceps*, (9) *Segond's bleeding-point forceps* (heavy), (10) *Horsley's lateral angular forceps*, (11) *angioclast*, (12) *Horsley's artery forceps* (curved on the flat), (13) *Pean's long bleeding-point forceps*, (14) *Hamilton's artery forceps*, (15) *Horsley's artery forceps*, (16) *Esmarch's torsion forceps*, (17) *Greig Smith's small forceps*, (18) *Ferguson's artery forceps*.

Elevation of the limb is of material assistance. The pressure of the hæmostatic forceps permanently stops the bleeding in many small cutaneous vessels. Doyen extended the application of this principle in his angiotribe.

Torsion has not been very extensively used. By torsion the intima and media are ruptured. They curl up, plug the lumen of the vessel, and are held by the twisted adventitia. If applied to large arteries the vessel should be caught, freed from its sheath and surrounding tissues, and held by one pair of forceps at a point above where it is desired to rupture the inner coats. The cut end of the vessel is then caught by another forceps and twisted until the rupture is felt to occur. It can scarcely be called a safe method and should be confined to small and cutaneous vessels. In such cases it is unnecessary to apply more than the one forceps and that to the cut end.

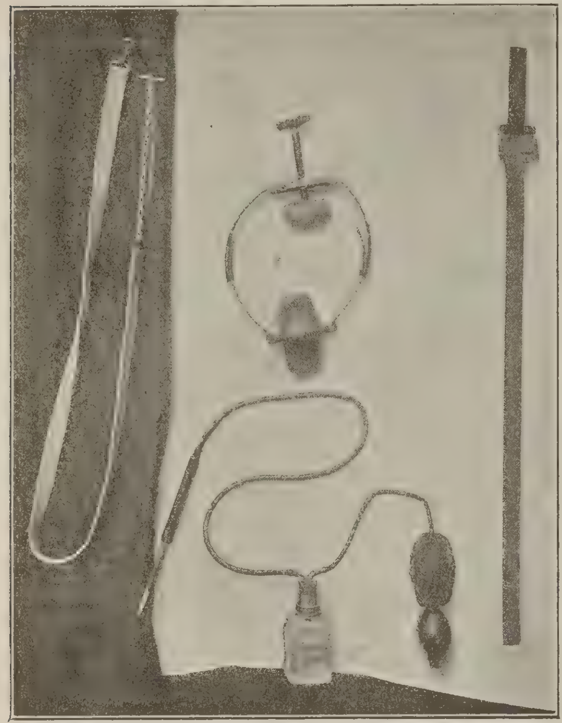

Fig. 2601.—Other Apparatus used in Arresting Hemorrhage. On the left-hand side, Esmarch's flat tourniquet; on the right, emergency tourniquet; in the centre, above, Skey's arterial compressor; in the centre, below, thermo-cautery apparatus.

The *cautery* is still sometimes found useful as a hæmostatic, particularly to arrest oozing from surfaces that are deep and inaccessible or where, because of the thinness of the tissue or its extreme friability, a ligature is contraindicated. The Paquelin thermocautery is now generally used, and for hæmostatic purposes the point should be only of a dull red heat, just turning black. If too hot it does not arrest the bleeding, and if too cold it sticks to the tissue. It is said to be less effective as a hæmostatic than the old cautery irons, but is much more convenient.

Hemorrhage from bone is sometimes troublesome. The bleeding vessel may have retracted into a bony canal, as happens, for example, in the case of the middle meningeal in the Hartley-Krause operation for removal of the Gasserian ganglion. If the vessel cannot be caught the bony canal may be plugged with gauze, an ivory peg or a bit of sterilized wood. For the oozing from the edges of divided bone Victor Horsley has prepared an antiseptic wax. It is composed of beeswax 7 parts, almond oil 1 part, and salicylic acid 1 part. It is often very helpful. Suprarenal extract or adrenalin may be found the most satisfactory of all. The writer used it successfully in a case of secondary hemorrhage in acute osteomyelitis.

Cold, locally applied, in the form of Leiter's tubes, or cracked ice, may be used in robust patients, for the arrest of oozing. It acts by stimulating the muscular coats to contract and reflexly may stimulate vessels situated beneath the surface. Cold should generally be avoided in the weak and in acute anæmia.

Heat, preferably in the form of hot saline solution, has a decidedly styptic action on tissues. The temperature may be 110° to 115° F., or as hot as the hand can bear.

Hot steam has been applied to bleeding surfaces as a styptic by Snegirew, with satisfactory results. He used it at a temperature of 212° F. in the cavity of the uterus (Senn).

Treatment of the Acute Anæmia resulting from hæmorrhage is only second in importance to the arrest of the bleeding which caused it. Stimulants must be exhibited with caution until the bleeding is stopped, as their effect is often to increase intravascular pressure. They have an important place in the treatment when used with discretion and good judgment. Opium is also valuable as an equalizer of the circulation and a determinant of blood to the cerebral centres.

Transfusion.—At the head of the list, however, stands normal saline solution, six-tenths of one-per-cent. solution. It may quickly be prepared by adding a drachm of salt to the pint of boiled water, cooled to a temperature of 100° F. A pint thrown into the rectum is useful. Much better and quicker results are obtained by injecting it beneath the skin in the infraclavicular and submammary regions. A double-branched tube with a hollow needle attached to each branch affords the most expeditious means of acomplishing this. Two pints can thus be introduced in from ten to twenty minutes. While it is being injected gentle massage should be continuously practised.

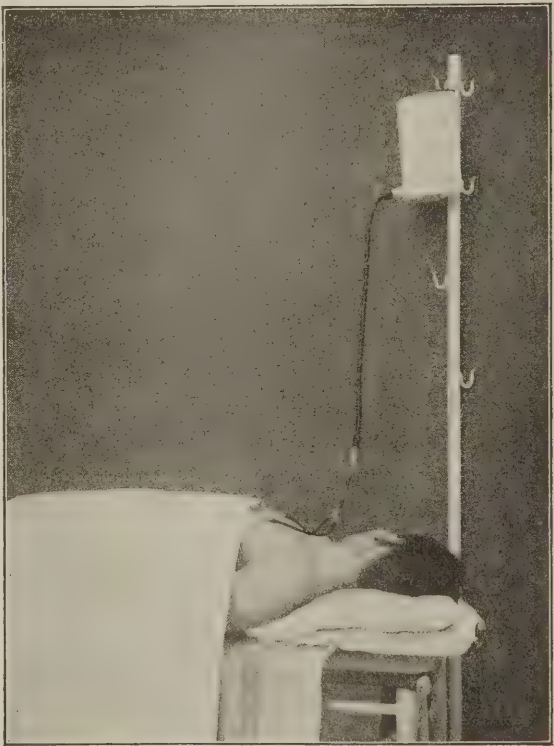

Fig. 2602.—Apparatus for Subcutaneous and Intravenous Injection of Saline Solution.

Many prefer in extreme cases to introduce the saline solution directly into the circulation through one of the superficial veins. A vein of the arm just above the elbow is usually selected. This little operation will be most readily accomplished by carefully laying bare the vein selected for a distance of an inch and then carefully passing beneath it a double ligature; tie the distal ligature; with a sharp knife make an incision in the wall of the vein just large enough to admit the end of the needle or nozzle; then tie the proximal ligature around the vein and the included needle or nozzle. As much as two or three pints of solution may be introduced. Then withdraw the nozzle and tie the proximal ligature, or pass a fresh ligature around the vein at that point. Precautions must be taken not to permit any air to enter.

In extreme cases until the bleeding is stopped elastic bands may be applied to the extremities close up to the body, thus saving the patient's blood. The foot of the bed should be raised eight or ten inches, thus sending the major part of the blood toward the great centres of the nervous and circulatory systems. This is a most effective method of auto-transfusion.

George E. Armstrong.

HEMORRHOIDS. See *Anus*, etc.

HEMP. See *Cannabis Sativa.*

HEMP, INDIAN. See *Cannabis Indica.*

HENBANE.—Hyoscyamus. "The dried leaves and flowering tops of *Hyoscyamus niger* L. (fam. *Solanaceæ*) collected from biennial plants" (U. S. P.). Of the three forms in which this plant presents itself, the most efficient one is insured by the language of this definition and of the accompanying description. The plant grows both as an annual and as a biennial. The former, and the latter during the first year of its growth, are to be rejected. The last-mentioned bears no flowers and is excluded by the words "flowering tops." Flowers are supplied by the annual form, but they lack, to a great extent, the "purple veins" called for by the description. Thus the highly active second year's growth of the biennial plant is the only form which affords a drug markedly characterized by yellow flowers with purple veins.

Henbane is a native of Europe and Western Asia, where it is a very common and abundant weed. It is also cultivated for medicinal purposes. Rarely, it occurs as a weed in the United States. It looks somewhat like the stramonium, but is not so large and is even more coarse-looking and more strongly viscid-hairy. The habit of the inflorescence is shown in the accompanying cut.

The following is the description of the drug:

Coarsely, roughly, and glandularly hairy throughout, except the corollas; larger leaves shortly and broadly petioled, 15 to 25 cm. (6 to 10 in.) long, and two thirds as broad, the upper becoming smaller and sessile; blades angularly ovate, acute, coarsely and angularly toothed or lobed, grayish-green or slightly yellowish-green; flowers in pseudo-racemes, short-pedicelled the calyx cylindraceous, somewhat contracted above the ovary, unequally five-toothed, the teeth triangular, acute, the corolla campanulate, five-lobed, sulphur yellow, with deep purple veins; capsule a two-celled pyxis; odor heavy, narcotic; taste bitter, somewhat acrid. From tobacco, henbane is distinguished by its incised leaves, from stramonium by its hairiness, and from belladonna by both these characters.

A full account of the composition and properties of henbane would constitute, to a great extent, a duplication of our account of belladonna. It may therefore be most profitably considered by comparing it with that drug.

The alkaloidal percentage of henbane is very much lower than that of belladonna. Some authorities place it below one-tenth of one per cent., while others state it as high as three-tenths. The best authorities agree upon 0.2 to 0.25 per cent. as the standard. The most of this alkaloid is *hyoscyamine*, separately treated Whether any atropine is present, is disputed, but if so, the amount is unimportant. Atropine may readily form during manufacturing operations, by conversion of the hyoscyamine. The most important variation from belladonna is in the presence of a small amount of hyoscine or scopolamine, also separately considered, in its alphabetical order.

The general similarity of henbane to belladonna in properties and uses will readily be inferred from its composition; yet the slight characteristic differences stated are sufficient to establish noticeable differences in these directions. These differences may be stated generally by saying that henbane is more distinctly sedative than belladonna, and that this sedative action extends to the cerebral, motor, and sensory functions, though less so to the latter. The marked tendency to delirium resulting from the use of belladonna may be quite absent in that of henbane, or even the opposite effect can be induced.

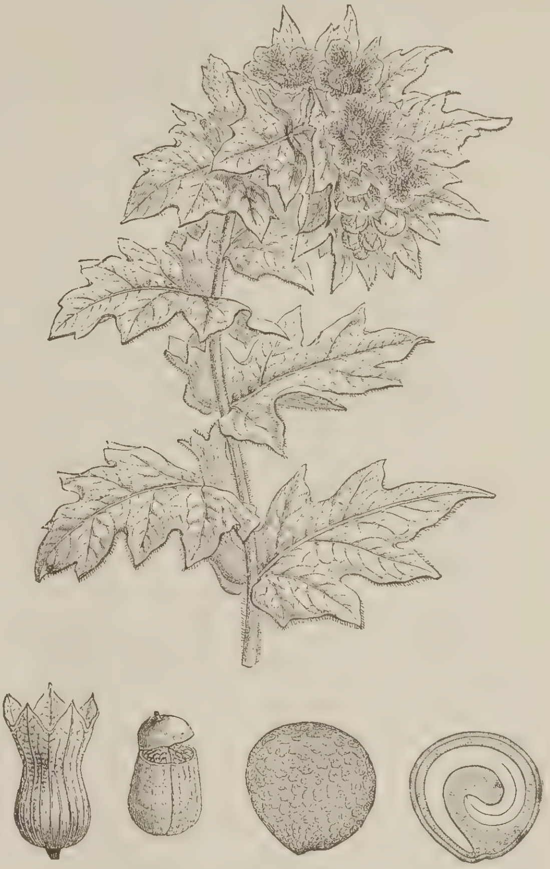

Fig. 2603.—Henbane, Plant and Fruit (about one-half natural size) — Seed Enlarged. (Baillon.)

Hence the distinct uses of henbane. It is scarcely employed in eye practice, though it produces very similar effects to those of atropine. If distinct cerebral-depressant effects are desired, it is better to give hyoscine itself, but when we wish the effects of belladonna, but desire to avoid its mental disturbances, henbane is chosen. Its commonest uses are intestinal and cystic, or renal. The former use is mostly in combination with purgatives which would otherwise be griping. At the same time that this unpleasant effect is averted, the henbane itself powerfully promotes peristalsis, and is therefore laxative, even excelling belladonna in this respect. The second-named use is as a sedative diuretic, relieving both painful and spasmodic conditions of the genito-urinary tract. Here again it is usually combined with other drugs, such local diuretics as buchu, kava, or oil of juniper. It is, however, often given alone in colic, cystitis, calculus, etc. It is commonly given in larger doses than belladonna. There are official an extract, the dose of which is 0.3 to 1 gm. (gr. ss.–iss.); a fluid extract, dose

0.3 to 1 c.c. (♏ v. to xv.); a 15-per-cent. tincture, dose 2 to 6 c.c. (fl ℥ ss.–iss. or ij.).

Henbane Seeds, though unofficial, are largely employed. They are light-brown, broadly kidney-shaped, and flattened, 1 to 1.5 mm. long and nearly as broad, and finely pitted. Thus they bear a close resemblance to stramonium seed, except in color and in their size, which is one-fourth to one-third as great. Their alkaloidal composition is about the same as of the herb, but they contain twenty-five per cent. of fixed oil, and a little resin. Since their percentage of alkaloid is a little greater, the dose of the seeds is about one-fourth or one-third smaller than that of the herb.

There are eleven species of hyoscyamus, and several of them, notably *H. album* L., have similar properties and uses to those of *H. niger*. *Henry H. Rusby.*

HENNA.—Under this name the leaves of *Lawsonia inermis* L. (fam. *Lythraceæ*) are extensively used in Eastern countries as a pigment for coloring the skin and hair and also as an astringent. Their use in jaundice is doubtless due to a superstition relating to their color. They contain a peculiar astringent resinous substance which has been called henotannic acid. *Henry H. Rusby.*

HENPUYE.—Goundou, Anakhré, Gros Nez, Dog Nose. Under the second, third, and fourth of these names the French writers, and under all of them except *gros nez* the English writers, describe a disease which up to the present has not been found outside of tropical or sub-tropical countries. The trouble in question consists of a peculiar form of exostosis or bony tumor, situated on each side of the nose. The growth is always bilateral, and usually symmetrical, but occasionally one side grows larger or more rapidly than the other. The exostosis is from the external surfaces of the nasal bone and the nasal process of the superior maxillary bone, with involvement of the body of the superior maxillary bone in severe cases. The trouble is confined to the bone; the nasal cavities, nasal cartilages, mouth, or orbits not being affected except mechanically by the presence or pressure of the tumor.

Geographical Distribution.—When first noticed goundou, or henpuye, was supposed to be limited to the Ivory Coast of West Africa and to the district watered by the river Comoë.[1] Since then it has been found in the neighboring territory of the Gold Coast;[2] and further afield at Sierra Leone (*Jour. of Trop. Med.*, ii., 145); but in every case the sufferer was a negro. But cases have since been reported of a Malay being affected in Sumatra (*Jour. of Trop. Med.*, iii., 11), a native in Southern China (*Jour. of Trop. Med.*, iii., 110), and some negroes in Jamaica, West Indies.[3] The case of goundou reported from Singapore (*Jour. of Trop. Med.*, July 1st, 1901, p. 213) was probably not one of goundou at all, as the tumor was not solid but consisted of a shell of bone covering cerebral meninges. We may safely say that the disease is confined to tropical and sub-tropical countries, with a predilection for the negro race.

General Description and Course of the Disease.—The trouble generally commences with a cold in the head followed by headaches chiefly over the frontal region; these headaches last for about a year, when a slight fulness is noticed on each side of the nose; as this swelling increases the headaches are apt to disappear. Sometimes the tumor will continue to grow for a year or two only, and sometimes it will develop slowly for many years. The overlying skin is apparently quite normal, being freely movable and quite healthy in appearance. The tumors are non-fluctuating, grow slowly and almost symmetrically with no tendency to suppurate, have an ovoid shape with the long axis outward and downward, become intensely hard, but are not as a rule painful except in wet weather. There is no tenderness on pressure. The size varies from a pea to an orange or an ostrich's egg,[1] but a pigeon's egg may be taken as an average of the dimensions attained. Of course the countenance is terribly deformed. In some cases a bloody or purulent discharge from the nose has been observed; in others there has been neither discharge nor sore. The cartilages of the nose are not involved, nor is the nasal duct; and there is no epiphora. Sometimes the tumor will press upon the anterior nares and compress the cavities, with the result that the voice obtains a nasal twang. The orbital cavities may be similarly pressed upon, but generally the growth of the tumor causes first a squint, then the patient may have to flex his head in order to see over the tops of the tumors; and later on, the tumors becoming still larger, there is a total obstruction of vision. But the eyeball is not destroyed. In Maclaud's cases[1] the patients were free from tuberculosis and syphilis. Chalmer's cases[2] had all suffered from yaws.

Etiology.—The natives of the Ivory Coast believed in a divine or diabolical origin of the disease. Maclaud[1] advanced the theory that the trouble was parasitic, being due to the larvæ of some dipterous insect; but the bilateral and symmetrical nature of the complaint remain unexplained by this hypothesis. Further, for the acceptance of this theory, it would be necessary to know the particular insect or insects with their exact habitat, and to ascertain whether this insect is found in West Africa, China, Sumatra, and the West Indies. Chalmers[2] considers the disease the result of yaws or frambœsia, which certainly seems more plausible; he asserts that goundou follows that disease, that it is caused by the absorption of the yaws poison from the mucous membrane of the nose and is carried by the lymphatics and small vessels through the foramina in the nasal process of the superior maxilla, and that in the cases which he observed there was a sore in and some discharge from the nose. But if goundou was caused by yaws there would have been hundreds of cases reported from the West Indies alone, where yaws has been carefully studied. Strachan considers it the result of atavism;[3] this theory seems the most probable of any, and, as in the somewhat similar case of the "horned men" of Africa, these bony outgrowths may be considered hereditary or at any rate characteristic of race. Of these "horned men" Macalister says "that outgrowths here may be really race characters is not to be entirely ridiculed, for the neighboring malar bone which here, according to O'Reilly's description, participates in the swelling, certainly shows certain race peculiarities, such as the bigger *Tuberositas malaris* of the Mongolians, and the *Processus marginalis*, whose race peculiarities have been pointed out by Werfer" (Bland Sutton, "Evolution and Disease," 1890, p. 197, English edition). It may be well to mention here the chief differences between goundou and the deformity of the horned men: (1) in the former the tumor is fairly parallel with the nasal bone, in the latter it is at right angles to it; (2) in goundou the exostosis is from the nasal process, in the "horned men" it is from the infraorbital ridge; (3) in goundou the malar bone is not affected, while it is apt to be involved in the latter condition.

Pathology.—The growth consists of a centre of cancellous bone, covered with a casing of hard compact bone, from which the periosteum can be very easily removed. The growth is in all probability an osteoplastic periostitis.

Treatment.—Iodide of potassium has been tried but without success. The only treatment is surgical. A longitudinal incision is made in the skin over the tumor, with perhaps a cross incision to allow more room, and the tumor can be removed with a saw, gouge, or bone forceps; the hemorrhage, which is slight, can generally be controlled by pressure; and under the ordinary aseptic precautions the parts unite by first intention.

R. J. E. Scott.

References:

[1] Maclaud: Archives de médecine navale, tome lxiii., p. 25.
[2] Chalmers: Lancet, London, 1900, i., p. 20.
[3] Strachan: Brit. Med. Journ., 1894, i., p. 189.

HEREDITY.—Heredity may be defined as a correlation between the variations of characteristics in individuals related to one another by birth.

The words used as the names of phenomena are apt to influence our conceptions of their character. This is particularly true of heredity. No doubt, most persons think of heredity as similar to the inheritance of goods and chattels. To them a son has received from his father the color of his eyes very much in the same way that he may expect to receive his seal ring or his watch. Such an idea is entirely foreign to the scientific conception of heredity, and in using the term it is necessary to keep in mind always its metaphorical character in order not to confuse the metaphor with the reality that it represents. Scientifically heredity is merely a special case of the correlation of variations.

This correlation may be *direct*, as between father or mother and son or daughter, between grandfather and grandson, etc.; or it may be *collateral*, as between brothers, sisters, brothers and sisters, uncles or aunts and nephews or nieces, between cousins, etc. In man and the higher animals inheritance is always *biparental*. That is to say, every individual has two parents; but there are cases in which there is only one parent, as in certain insects and crustacea that produce young most frequently by means of parthenogenetic eggs, and among some of the lower animals and the plants, which frequently produce new individuals by means of buds, underground shoots, etc. In such cases inheritance is *uniparental*.

Of direct inheritance there are three important types: (1) *blended* inheritance, where the child is intermediate in character between the two parents, as in stature; (2) *exclusive* inheritance, where the character of the child is like that of one parent but not like the other, if they differ, as in the color of the eyes; (3) *particulate* inheritance, where the characters of both parents appear in the child, but do not blend; for example, a pup may have spots, some of which are of the color of the mother, while others are like the coat of the sire, or a boy may have a nose like his father and eyes like his mother.

Variability.—Variation is deviation from the type, and for most statistical inquiries the type taken as the standard is the arithmetical mean of the population or group. Deviations are of two kinds, abnormal, such as the "sports" of the horticulturist, and normal variations, which may be observed in every family or other group of individuals. The normal variations are found to be distributed about the mean in a way that may be expressed by certain mathematical formulæ derived from the theory of probability and chance (see articles *Evolution* and *Variation*). The relations most frequently met with are represented in Fig. 2604.

The rectangles in this figure taken together form what is called a polygon of frequency, and the flowing curve is a theoretical curve of chance, or probability, that has been fitted to the polygon, which represents graphically the observed facts. Now if we plot the curves of two sets of observations, employing units of scale of the same value in both, the differences in the forms of the curves will depend upon the number of individuals in the most frequent class, or *mode*, that is the tallest rectangle, and, supposing the curve to be symmetrical, upon the amount of *deviation* on either side of the mean. The amount of deviation, that is the *variability* of the group, is measured by what is called the *standard deviation* (the "mean error" of the mathematicians). This is obtained by multiplying the square of the deviation from the mean of each class by its frequency, adding all the results together, dividing by the total number of observations, and finding the square root of the quotient $\left(\sigma = \sqrt{\frac{\Sigma\,(x^2 f)}{n}}\right)$. The Greek letter σ is used as the symbol for this quantity. Its relation to the curve of frequency is shown at σ in Fig. 2604.

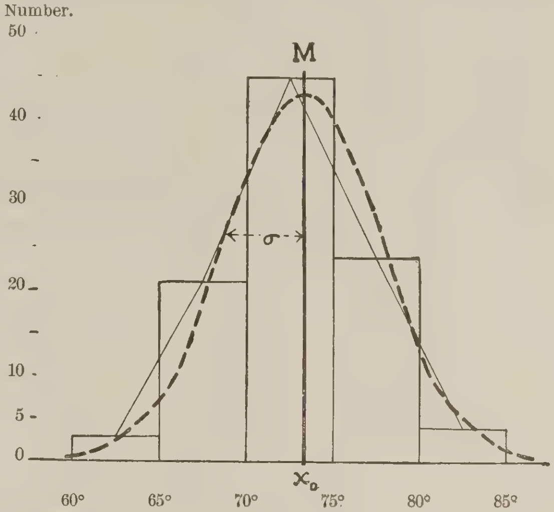

FIG. 2604.—Graphic Representation of a Series of Variations. Variation in the width of the angle at the apex of the shell in *Purpura lapillus*. Mx_0, position of the mean; σ, standard deviation.

Correlation.—"Two variable organs are said to be correlated when the variation of one is accompanied on the average by more or less variation of the other, and in the same direction" (Galton, 1888). In order to determine the degree of *correlation* between two organs accurately, it is necessary to have a large number of observations and to arrange them in a "correlation table" like the one given below, Table I.

TABLE I.—CORRELATION IN THE LENGTH OF FIRST JOINT OF INDEX FINGERS OF WOMEN, RIGHT AND LEFT HANDS. (From Whitely and Pearson.)

LEFT HAND (RELATIVE CLASSES).	RIGHT HAND (SUBJECT CLASSES).													Totals.
Length of joint in inches.	1.95 to 2.00.	2.00 to 2.05.	2.05 to 2.10.	2.10 to 2.15.	2.15 to 2.20.	2.20 to 2.25.	2.25 to 2.30.	2.30 to 2.35.	2.35 to 2.40.	2.40 to 2.45.	2.45 to 2.50.	2.50 to 2.55.	2.55 to 2.60.	
1.90 to 1.95	1	1	1	....	....	....	....	....	....	....	....	....	....	3
1.95 to 2.00	1	2	....	....	....	....	....	....	....	....	....	....	....	3
2.00 to 2.05	1.5	7.5	13	4	....	4	....	....	....	....	....	....	....	27
2.05 to 2.10	1.5	2.5	12	17	3.5	1	....	....	....	....	....	....	....	37.5
2.10 to 2.15	....	....	3.5	21	32	7	1	....	....	....	....	....	....	64.5
2.15 to 2.20	....	....	....	4.5	38.75	35.5	9.75	1.5	....	....	....	....	....	90
2.20 to 2.25	....	....	....	1.5	7.25	45.25	45.25	5.25	0.5	....	....	....	....	105
2.25 to 2.30	....	....	....	....	1	8.25	36.5	28.5	2.25	....	....	....	....	76.5
2.30 to 2.35	....	....	....	....	....	....	7	41.25	24.5	3.25	....	....	....	76
2.35 to 2.40	....	....	....	....	....	....	1	5.5	17.75	13.5	0.25	....	....	38
2.40 to 2.45	....	....	....	....	....	....	....	....	3.5	12	6.5	0.5	....	22.5
2.45 to 2.50	....	....	....	....	....	....	....	....	1	2.75	1.75	0.5	....	6
2.50 to 2.55	....	....	....	....	....	....	....	....	....	....	1	....	0.5	1.5
2.55 to 2.60	....	....	....	....	...	....	....	....	....	....	....	....	0.5	0.5
Totals	5	13	29.5	48	82.5	98	100.5	82	49.5	31.5	9.5	1	1	551

The construction of this table may be understood from a consideration of the first column of entries. Five fingers of the right hand were found in which the length of the first joint was between 1.95 and 2.00 inches. These form a "*class.*" Of the corresponding fingers on the left hand only one was of the same length. One was shorter, 1.90 to 1.95 inches; and three were longer, one of these being exactly 2.05 inches long, was placed half in the relative class above and half below that mark. Thus the totals at the base of the columns show the number of fingers in each class of the right hand, while the figures in the columns show the number of associated fingers in each class of the left hand. The right hand is said to be the *subject* and the left hand the *relative* and each column is called an *array*. Conversely, we may, without altering the table, regard the left hand as subject, and the right hand as relative, and the arrays would then be the rows of figures, which are added up in the last column.

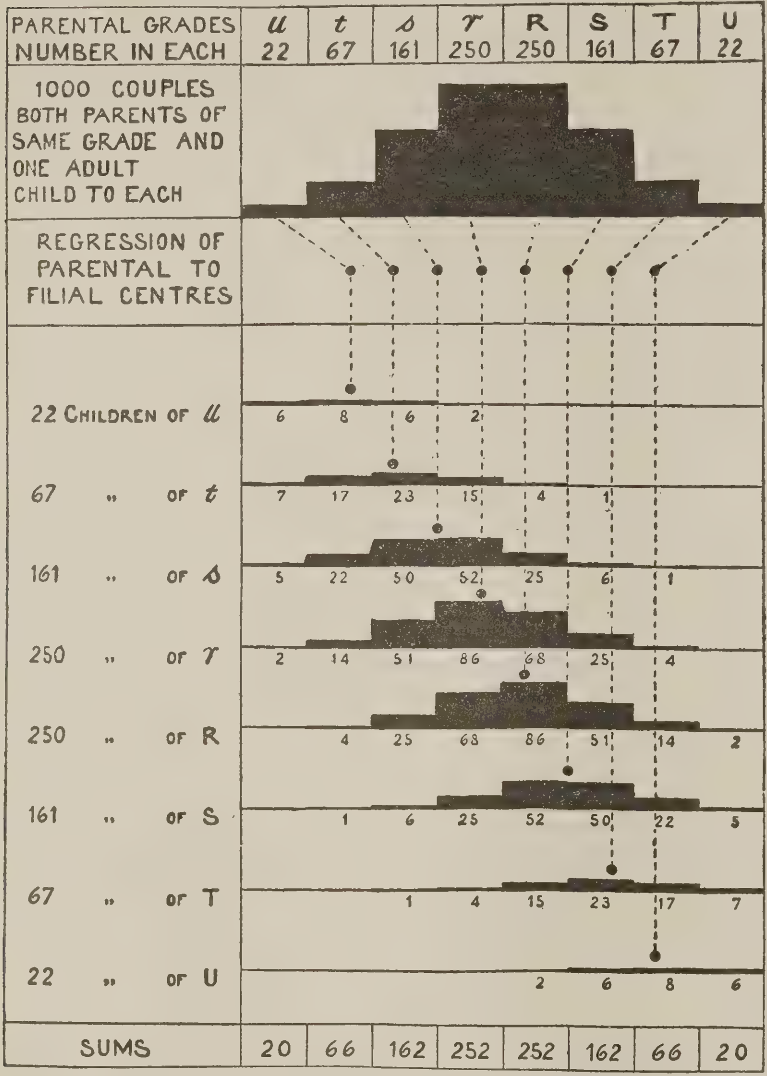

FIG. 2605.—Galton's Standard Scheme of Descent. (From Galton.)

Now by this means we may study the correlation of any pair of organs in respect to any characteristic that permits of being expressed in quantitative terms. We may compare not only different organs or parts of the same individual, but also any suitable characteristics of distinct individuals, provided they are related in some constant way, as for example husbands and wives, fathers and sons, brothers and sisters, etc. But fathers and sons, and brothers and sisters are related by birth, and when we study the correlation between them we are studying what is called natural inheritance.

The Phenomena of Heredity.—Some of the most important results of a long series of studies of inheritance are represented graphically in Galton's "Standard Scheme of Descent," which is reproduced in Fig. 2505. This scheme represents a supposed case in which there are a thousand couples of parents and in which each parent is mated to another of the opposite sex having relatively the same deviation from the mean in the character measured, and each couple is supposed to have one adult child. The parents are divided into eight classes having the relative frequency and deviation from the mean represented by the polygon of frequency at the top of the figure. The classes *R*, *S*, *T*, *U*, present positive deviations from the mean, and *r*, *s*, *t*, *u*, have corresponding negative deviations. The distributions of the variations in the children of each parental class are represented by the polygons below—drawn to the same scale. An attentive study of this diagram reveals many interesting things. In the first place the filial polygons are similar in form to the parental one. A dot above each filial polygon indicates the position of its mean; and the second point of interest is that the mean of any group of children does not correspond with the mean of its parents, nor with the mean of parents in general, but lies between the two. Still the mean of the children of *u* is much nearer the mean of *u* than the children of *U*. There is evidently a correlation between the parents and their offspring. But this is not perfect, for, while parents with negative deviations from the mean have children whose deviations on the average are negative and those with positive deviations have children who deviate on the average in the positive direction, still in each case the mean of the children deviates from that of their parents and toward the mean of parents in general, which is probably the same as the mean of the population of which they form a sample. This tendency for the mean of the children to deviate from the type of their parents toward the type of the population in general is called *regression*. The results that follow from the laws of variability and regression in children are of considerable interest and importance. If we suppose parents of grade *U* to be especially gifted in some way, we see that when both parents are of this grade they may hope to have children equally gifted in the proportion of 6 to 22 or, say, two children equally gifted with themselves in a family of seven. On the other hand, if we take twenty children in grade *U*, only six will have parents as gifted as themselves, and two of them will be derived from very mediocre parents of grade *R*. Nevertheless, the chances that the exceptional parents will produce equally exceptional children as against mediocre children are 6 to 2, while the chances of mediocre parents of grade *R* are 2 to 154. The reason that there are so many gifted children of relatively mediocre parents is that there are so many mediocre parents. When we add up all the children in each grade, as is done at the bottom of the scheme, we find that the mean and variability of children in general is nearly the same as of parents in general. They would have been more nearly the same if we had taken larger numbers. So, if no selection is being made, the population as a whole in one generation will be the same in character as the previous one.

For the exact study of inheritance use is made of correlation, or regression, tables similar to Table I. We have converted Galton's scheme of descent into such a table (Fig. 2606) represented graphically by placing each filial polygon as an array beneath the centre of the corresponding parental grade, or class; and adding up the filial grades at the right. In this diagram the parental deviations are measured on the horizontal scale, and the filial deviations on the vertical scale. The heights of the shaded areas represent the frequency of each parental class, and widths represent frequency in the filial classes.

The line *YY* occupies the position of the parental mean and the line *XX* the position of the filial mean. The two lines cross at right angles in the middle of the diagram. The line *AB* is a straight line drawn through the position of the mean (represented by a round dot) in each array and through the point of intersection of the lines *XX* and *YY*. It is called the *regression line*. In an actual regression table it would not pass through every dot, but would be placed so that the deviations of the means above and below it would balance one another as nearly as possible. Now the slope of this line may be measured by taking the ratio between the distance of any point on the line *AB* from the line *XX* and the distance from the same point to the line *YY*. A point three spaces to the left or right of the line *YY* will be two spaces below or above *XX*. So the slope of *AB* may be said to be 2 in 3, or $\frac{2}{3}$. This quantity (in this case, $= \frac{2}{3}$) is called the *coefficient of regression*. It is the quantity which multiplied by the deviation of a parental class from the mean of parents will give the average deviation of its array of children from the mean of children. For example, parents of grade *S* deviate on the average one and one-half spaces of our scale from the mean of parents. $1\frac{1}{2} \times \frac{2}{3} = 1$, which is the deviation of the mean of the children of *S* from the mean of children in general. The slope of the regression line will differ in different cases. If there were no regression, the deviations of the parental class and of the array of offspring would be the same, and the regression line would occupy the position *CD*. On the other hand, if there should be complete regression, the mean of the filial array would be the same as the mean of children in general, no matter how great the deviation of their parents, and then the regression line would coincide with *XX*. The regression line, then, may lie anywhere between the position *CD* where the coefficient is 1 and *XX* where it is 0. So the less the regression the greater the coefficient, and *vice versa*. But it is evident that the slope of the line may depend on several factors. If we should plot the parental deviations on a scale having units twice as long as in the scale of filial deviations, the slope of the line would be reduced one-half. But having equal units of scales, we should find the same result if the variability of parents were twice that of children. Now differences of variability are found in the practical study of correlations and must be taken into account. This is done if we regard the slope of the regression line as the resultant of two factors: the ratio of the two variabilities, and an unknown factor that is called the *coefficient of correlation*.

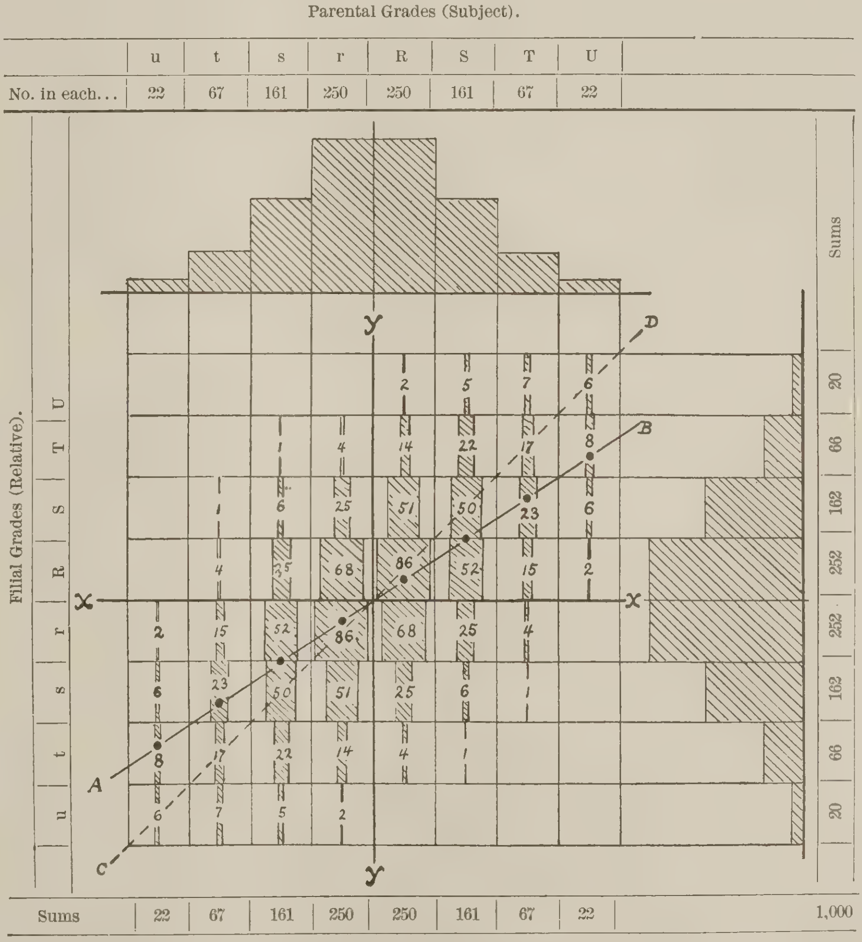

FIG. 2606.—Regression Table, Children on Parents. One thousand parents with mates of same grade and one adult child to each. (Data from Galton.)

Putting this into symbols, in this case $\frac{2}{3} = \rho\frac{\sigma_2}{\sigma_1}$, where σ_1 = standard deviation of parents, σ_2 = standard deviation of children, and ρ = coefficient of correlation. From these considerations Pearson has derived a general formula* for calculating the value of ρ as follows:

$$\rho = \frac{\Sigma\,(x\;y\;f\,)}{n\;\sigma_1\;\sigma_2}$$

When there is perfect correlation $\rho = 1$; when there is no correlation $\rho = 0$. In the theoretical example that we have been studying parents and children are supposed to have the same variability,—that is, $\sigma_1 = \sigma_2$. In such a case, of course, $\rho = \rho\,\frac{\sigma_2}{\sigma_1}$, and the slope of the line *AB* represents the coefficient of correlation as well as that of regression.

In practice the coefficients of regression and correlation are found to be essentially the same in collateral inheritance; and also in direct inheritance, if we take into account only one parent of each couple and suppose the other to be chosen at random. The value of ρ calculated from observations in a number of such cases is given in Table II. (see below).

The Mid-Parent.—But in man and the higher animals inheritance is always biparental, and in order to study the true relations between parents and offspring it is necessary to take both parents into account. This involves the correlation of three variable quantities. In order to avoid this difficulty the two parents are combined into a single artificial individual called the *mid-parent.* For example, Galton found that the mean stature of women in England is 1.08 less than that of men. So in order to study the inheritance of stature, he converted the stature of each mother and daughter into its "male equivalent" by multiplying it by 1.08; and he obtained the mid-parent by taking the mean of the father's stature plus the mother's male equivalent. Thus if the father had a stature of 70 inches and the mother of 66 inches, the stature of the mid-parent would be

$$\frac{70 + 1.08 \times 66}{2} = 70.64$$

In the study of heredity, however, deviations from the mean are used more frequently than the absolute dimensions of organs. Therefore Pearson has generalized and simplified Galton's formula for the mid-parent by putting it in this form:

$$\tfrac{1}{2}\left(h_1 + \frac{\sigma_1}{\sigma_2}h_2\right) = \mathrm{H}$$

where h_1 = the deviation in the particular father from fathers in general; h_2 = deviation of mother mated to this father from the type of mothers, σ_1 = standard deviation of fathers in general; σ_2 = standard deviation of mothers; and H = deviation of the mid-parent from the type of mid-parents. This formula will apply to measurements of any organs, and it enables one to calculate easily either the deviation or the absolute value of the organ in the mid-parent. Having calculated the mid-parents, one may study the correlation between children and mid-parents, just as if the latter were single individuals.

The Law of Ancestral Heredity.—Now we are prepared to consider the influence of each ancestor upon the characteristics of the child. Returning to Fig. 2606, if there were no inheritance, the means of all the arrays would lie along the line *XX;* and we may think of heredity as a force† tending to pull each array away from *XX* in the direction of its parental grade, that is, toward the line *CD.* Now the question is, How much of this pull is exerted by each parent, grandparent, great-grandparent, etc.?

From the study of a variety of data, Galton came to the conclusion that, of the total heritage, the mid-parent contributes one-half, the mid-grandparent one-quarter, the mid-great-grandparent one-eighth, and so on. Or, if h be the mean deviation of a given group of offspring from offspring in general and H_1, H_2, H_3, etc., be the deviations from their mid-parental means of the mid-parent, mid-grandparent, etc., of these offspring, then

$$h = \tfrac{1}{2}\,\mathrm{H}_1 + \tfrac{1}{4}\,\mathrm{H}_2 + \tfrac{1}{8}\,\mathrm{H}_3 \;.\;.\;.\; \text{etc.}$$

If the mid-parent contributes one-half, each parent will contribute one-quarter. So we may state Galton's law in the words of Pearson as follows:

"Each parent contributes on an average one-quarter, or $(0.5)^2$, each grandparent one-sixteenth, or $(0.5)^4$, and so on, and that generally the occupier of each ancestral place in the *n*th degree, whatever be the value of n, contributes $(0.5)^{2n}$ of the heritage."

Galton's series, $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16}$, . . . etc. = 1, is a geometrical series having a total of one. But the values $\frac{1}{2}$, $\frac{1}{4}$, etc., may not be true for all species, and Pearson, therefore, proposes to substitute the symbols γa, γa^2, γa^3, etc., in which there are two factors, one constant in each generation (γ), and one which varies in a geometrical series (a, a^2, a^3, . . . etc.). Galton's law would now take the form

$$h = \gamma\,(a\,\mathrm{H}_1 + a^2\,\mathrm{H}_2 + a^3\,\mathrm{H}_3 \;.\;.\;.\; \text{etc.}).$$

TABLE II. (From Pearson.)

Relationship.		Material.	Organs.		Coefficient of correlation ρ.
Subject.	Relative.		Subject.	Relative.	
Father	Son	Middle class English	Stature	Forearm	0.369
Father	Son	Middle class English	Stature	Stature	.396
Father	Daughter	Middle class English	Stature	Stature	.360
Mother	Son	Middle class English	Stature	Stature	.302
Mother	Daughter	Middle class English	Stature	Stature	.284
Mother	Son	North American Indians	Head index	Head index	.370
Mother	Daughter	North American Indians	Head index	Head index	.300
Sire	Foal	Thoroughbred horses	Coat color	Coat color	.517
Dam	Foal	Thoroughbred horses	Coat color	Coat color	.527
Grandsire	Offspring	Thoroughbred horses	Coat color	Coat color	.335
Grandsire	Offspring	Basset hounds	Coat color	Coat color	.134
Brother	Brother	Middle class English	Stature	Stature	.391
Brother	Brother	North American Indians	Head index	Head index	.379
Colt	Colt	Thoroughbred horses	Coat color	Coat color	.623
Sister	Sister	Middle Class English	Stature	Stature	.444
Sister	Sister	North American Indians	Head index	Head index	.489
Filly	Filly	Thoroughbred horses	Coat color	Coat color	.693
Brother	Sister	Middle class English	Stature	Stature	.375
Brother	Sister	North American Indians	Head index	Head index	.340
Colt	Filly	Thoroughbred horses	Coat color	Coat color	.583
Whole brethren	Whole brethren	Basset hounds	Coat color	Coat color	.508

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* In this formula x and y are the deviations from their means of the two organs of an associated pair, as father and son, f is their frequency, n is the total number of pairs, and Σ is the symbol for addition.

When there is no correlation $\Sigma\,(x.\,y.\,f\,) = 0 \;\therefore\; \rho = 0$.

When correlation is perfect $y = x$ and $\sigma_2 = \sigma_1$.

Then $\frac{\Sigma\,(x.\,y.\,f\,)}{n} = \frac{\Sigma\,(x^2.\,f\,)}{n} = \sigma^2$ and $\frac{1}{\sigma_1\;\sigma_2} = \frac{1}{\sigma^2}$

$\therefore\; \frac{\Sigma\,(x.\,y.\,f)}{n\;\sigma_1\;\sigma_2} = \frac{\sigma^2}{\sigma^2} = 1 = \rho.$

† Note that this is a purely metaphorical expression.

Now when $\gamma(a + a^2 + a^3 \ . \ . \ . \ \text{etc.}). = 1$,

$$\frac{\gamma a}{1-a} = 1 \therefore \gamma = \frac{1-a}{a} = \frac{1}{a} - 1 \therefore a = \frac{1}{1+\gamma}$$

So we may eliminate the quantity a from the formula by substituting this value and our formula becomes:

$$h = \gamma\left(\frac{1}{1+\gamma}\,H_1 + \frac{1}{(1+\gamma)^2}\,H_2 + \frac{1}{(1+\gamma)^3}\,H_3 \ . \ . \ . \ \text{etc.}\right)$$

But if we wish to be very exact, we must take into account the fact that the variability of all the offspring, σ, may differ from the variability of the successive generations of mid-parents, σ_1, σ_2, σ_3, etc., so the ratios of these standard deviations must be included in our formula, which then becomes:

$$h = \gamma\left(\frac{1}{1+\gamma} \cdot \frac{\sigma}{\sigma_1} \cdot H_1 + \frac{1}{(1+\gamma)^2} \cdot \frac{\sigma}{\sigma_2} \cdot H_2 + \frac{1}{(1+\gamma)^3} \cdot \frac{\sigma}{\sigma_3} \cdot H_3 \ . \ . \ . \ \text{etc.}\right).$$

This is the *law of ancestral heredity* as given by Pearson in its complete form. It is undoubtedly a generalization of great importance, and for a number of years to come the chief aim of a large number of scientific investigators will be to test and criticise this law. According to this theory the degree of correlation between parents and offspring will depend upon the hereditary influence represented by the symbol γ. In Galton's original formula $\gamma = 1$, very nearly. The effects of different values of γ are shown in the following table:

TABLE III.—HEREDITY—DIRECT LINE. (From Pearson.)

Offspring and—	COEFFICIENT OF CORRELATION, ρ.		
	When $\gamma = 1$.	When $\gamma = 0.9$.	When $\gamma = 2.35$.
Parent	.3000	.2851	.4000
Grandparent	.1500	.1425	.2000
Great-grandparent	.0750	.0713	.1000
Great-great-grandparent	.0375	.0356	.0500
*n*th order grandparent	$6. \times (\frac{1}{2})\ n.$	$.5702 \times (\frac{1}{2})\ n.$	$.8 \times (\frac{1}{2})\ n.$

These theoretical values of the coefficient of correlation should be compared with the values obtained from observation in Table II. From the study of "a really considerable amount of quantitative measurements of heredity" Pearson concludes that the values of the coefficient of heredity given in the first column of Table III. (when $\gamma = 1$) "seem to fit the observed facts fairly well in the case of *blended* inheritance." The coat color of horses and dogs appears to belong to one of the other types of heritage, either exclusive or particulate; and it seems to be doubtful if these types come under Pearson's law of ancestral heredity.

Table II. gives cases also of collateral inheritance, and the theoretical values, when $\gamma = 1$, are given below:

TABLE IV.—COLLATERAL HEREDITY. (From Pearson.)

Relatives.	Correlation when $\gamma = 1$.
Brothers	.4000
Uncle and nephew	.1500
Great-uncle and nephew	.0625
First cousins	.0750
First cousins, once removed	.0344
Second cousins	.0172
Second cousins, once removed	.0082
Third cousins	.0041

We see that brothers are more closely related than parent and offspring, and the correlation between first cousins is the same as that between offspring and great-grandparent.

Uniparental Inheritance.—The coefficient of correlation, or heredity, between brothers is of special interest because of its similarity to certain other correlations.

In Galton's standard scheme of descent it is supposed that both parents are of the same grade and the coefficients of regression and correlation were found to be equal and have the value $= \frac{3}{5}$. When $\gamma = 1$ this value would be 0.6. But this is a condition that would not be met with ordinarily in nature. More often there is little or no correlation between husband and wife in the characters measured, that is, mating is at random so far as the character in question is concerned, and under these conditions the mid-parents will be less variable than the offspring; and therefore the coefficients of regression and correlation will differ. Pearson has shown that, when $\gamma = 1$, if there be no sexual selection, the coefficient of regression of offspring on mid-parents remains 0.6, but the coefficient of correlation is reduced to 0.4242. With random mating, then, the offspring will resemble their mid-parents more nearly than they will either single parent, the correlation between single parents and offspring under these conditions being = 0.3.

Dr. E. Warren has made an interesting comparison between these results and observations that he has made upon heredity in parthenogenesis. Daphnia is a small fresh-water crustacean that reproduces rapidly under favorable conditions by means of parthenogenetic eggs, thus presenting good material for the study of uniparental inheritance. From 23 individuals Warren obtained 96 young in broods of three to six, and these were allowed to grow up. He measured the length of the first joint of the second antenna of the right side in each individual and recorded the results in thousandths of the body length. Constructing a correlation table he found a coefficient of regression of offspring on mothers of 0.619 ± 0.0809, and a coefficient of correlation of 0.466 ± 0.0539, the offspring being more variable than the mothers. While these results are somewhat uncertain, owing to the small number of individuals measured, the resemblance between these results and those obtained with mid-parents is striking and somewhat surprising.

Very recently (1901) Pearson has published the results of twenty-two series of correlations of serially homologous organs (homotypes) in plants, as, for example, the correlation between the number of prickles on the leaves of a holly tree, of the sori on the fronds of a fern plant, etc. The result was an average coefficient of correlation of 0.4570.

In nineteen cases of fraternal correlation in the animal kingdom he obtained a mean coefficient of correlation = 0.4479. These results from various sources are compared in the following table:

TABLE V.—CORRELATIONS.

Relationship.	Coefficients.
Offspring and mid-parents (theoretical)	0.4242
Offspring and mothers, Daphnia (observed)	0.466
Homologous organs on same individual (observed)	0.4570
Brothers (observed	0.4479

The similarity of these coefficients may be the accidental result of dissimilar causes. But Pearson has suggested that they may have a profound significance. The ova and spermatozoa that are produced so abundantly by a single individual are homologous organs, and may be expected to exhibit the same degree of correlation that other homologous organs do. As we shall see later, the characters of brothers depend to a great extent upon the characters of the germ cells from which they are derived. So there may be some one fundamental law of growth that determines the variability and heredity alike of individuals and of organs.

Exclusive Inheritance.—So far we have dealt chiefly with heritages that are blended in the offspring. But there are some characteristics that appear in the individual child as if derived from one parent only. Galton found such to be the case in regard to the color of the eyes. If one parent have dark eyes and the other light eyes, the eyes of each child will be either light or dark, seldom intermediate in color. The laws governing this form of inheritance are so uncertain at the present time that they need not be considered in this article.

Particulate Inheritance.—Every one will recall instances of particulate inheritance. It is especially well shown when individuals of two races are crossed. The writer has in mind a family in which the father was a European and the mother a mulatto. Some of the children had pronounced negro features with fair complexions, others had dark skins and regular features; the characteristics of the two parental races were not evenly blended in any one of the children. Particulate inheritance is so similar to exclusive inheritance that it is sometimes difficult to determine to which type a given case belongs, as is true for example in regard to the color of the hair of horses and dogs.

Prepotency.—Sometimes the offspring on the average will resemble one parent more than the other, and then the parent with which the correlation is the greater will be said to be prepotent. Breeders find as a rule that pure-bred animals are prepotent over mongrels. The prepotency may affect all offspring alike or it may affect only one sex. Abnormal variations are said to be highly prepotent, and Darwin gives a number of cases of the inheritance of such variations by one sex only.

Inheritance at Corresponding Periods of Life.—Correlations may be observed not only between adult parents and adult offspring, but also between the immature stages of parent and offsprings, and, of course, these correlations come at corresponding periods of life, or there would be no regularity in the course of development. But it has been observed that abnormalities in parent and offspring tend to appear likewise at corresponding periods of life. Of this Darwin gives a number of examples.

Characters that may be Inherited.—In general all congenital characters exhibit the phenomena of heredity, either of one type or another. This includes not only normal variations but also various abnormalities and those constitutional weaknesses that predispose the subject to disease. Pearson has shown that fertility may be inherited and every horticulturalist knows that variability is an inheritable characteristic. As to the inheritance of modifications acquired as the result of external influences upon the cells of the body, we have but few observations of value. The results from Fay's observations on the inheritance of deafness are given in the following table:

TABLE VI.—INHERITANCE OF DEAFNESS.

Condition of parents.	Number of children.	Per cent. deaf.
Both deaf, acquired	1,720	2.3
Hearing and deaf, acquired	713	2.2
Deaf, congenital and acquired	1,820	6.3
Hearing and deaf, congenital	528	11.9
Both deaf, congenital	779	25.9

The difference of the results between the cases in which congenital deafness appears in the parentage and cases in which it apparently does not is very striking. It is possible that it might be still more so if it were not for the difficulty of distinguishing in every case between congenital and acquired deafness, a difficulty which may perhaps account for the appearance of even the small percentage of deaf children credited to parents that appear to have acquired deafness. (See *Evolution.*)

Reversion.—The discussion of reversion and atavism is reserved for another place. (See article *Reversion.*)

Telegony.—Many breeders of domestic animals are firmly convinced that a previous sire may influence the progeny of a subsequent one. This supposed influence is called telegony and is regarded as a phenomenon of heredity. The subject has been investigated experimentally by Ewart, using horses and zebras, and he found no evidence of such an influence. Pearson has attacked the problem from the statistical point of view and likewise reached negative results.

In plants there is a phenomenon called *xenia.* In Indian corn when two varieties are crossed the maternal part of the fruit takes on the characteristics of the male parent, which one would not expect to appear until the formation of the fruit of the next generation. De Vries and Webber have explained this as due to a process of double fertilization first observed by Nawaschin and Guignard (see *Impregnation*).

In concluding our review of the phenomena of heredity it should be noted that little is to be learned by the study of isolated cases. We can acquire ideas of value in regard to heredity only by dealing with large numbers of observations by approved statistical methods. And it has been with the hope of giving some notion of the first principles of that new and important branch of biological science that we have devoted so much space to the subject. We now turn to the theories of heredity.

THEORIES OF HEREDITY.

Importance of the Subject.—We are all interested in the question as to how we have come to be what we are, and we have seen that what we call the principle of heredity has been an important factor in determining the present condition, not only of every human being, but also of every living thing whether animal or plant. We now turn naturally to the study of the mechanism of heredity. But this is a thing which is not open to direct observation, and the best that we can do is to construct a theory of heredity from such facts as we can observe. Such an inquiry is not only of importance to the students of pure science desirous of fully comprehending the origin of organic individuals, but is equally important to the practical breeder of domestic animals and plants wishing to maintain his stock at the highest value and to the practical philanthropist anxious for the perfection of the human species. The medical practitioner is also constantly face to face with questions of heredity, and the value of his advice in such cases will depend on whether or not they are founded upon a sound theory.

We often hear it stated that theory is one thing and practical experience is another. But all experience goes for nothing, if it does not lead to the formation of correct theories. It is the comprehension of theories that makes the difference between the skilled engineer who plans great bridges or powerful machines and the day laborer who mixes the mortar or hammers the iron; and when we realize the immeasurably greater complexity of the simplest organism over the most intricate mechanism of human construction, we can see how much more important a correct theory is in the effort to improve the races of higher animals and plants.

Requirements of a Theory of Heredity.—A theory of heredity is not required to explain the multiplication of organisms, but it must explain the relations of form between parent and offspring. These relations are expressed by the terms heredity and variation. We have seen how intimately connected variation and heredity are with one another, that they are in fact but the opposite phases of the same phenomena. A theory of heredity, therefore, must be also a theory of variation. But heredity and variation are both the result of the process of development and to explain them one must first explain development. The embryologist has explained the development of any structure sufficiently for his purpose when he has shown how this structure is the necessary result of a certain observed order of cell division, growth, and differentiation. For him the cell is the fundamental structure, and unequal growth, fusion, and fission of tissues are fundamental processes. For the student of heredity, however, it is necessary to go deeper and to try to discover the fundamental structure of the cell itself and to investigate the minute processes of cell division to determine, if possible, the causes that result in unequal growth and differentiation and thus control the development of the organism as a whole. A theory of heredity and variation, therefore, must be also a theory of development in the deepest sense. It follows from this that our theory, to be valid, must be capable of explaining all of the phases of development, including direct development, both sexual and asexual, metamorphosis, sexual dimorphism, other forms of polymorphism, regeneration of lost parts, and the alternation of generations. It will readily be seen, moreover, that such a theory necessarily involves some conception as to the essential structure of living matter.

The Fundamental Conceptions in Theories of Heredity.—Theories of heredity are nearly as numerous as the thinkers upon this subject. It would be very interesting to take up the views of each author in their historical order and to study the effects of previous observations and deductions upon them and their influence in turn upon the opinions that have been expressed later. If we should do this, we should find, however, that in spite of multiplicity of distinct theories, there is a comparatively small number of fundamental conceptions, one or more of which form the basis of each of the theories. We should find, also, that as the knowledge of anatomy, physiology, and embryology has advanced with the invention of more precise methods of research, the theories of heredity have come to depend more and more upon observed facts and less upon *a priori* principles. The result, however, has not been, as one might suppose, to simplify the theories, but rather to make them more complex. In fact, the more we know about heredity the more wonderful the phenomena appear and the more difficult becomes their explanation. To discuss all of these theories in their historical relations would unduly extend this article, and we shall have to content ourselves with an examination of the fundamental conceptions underlying them. These conceptions may be enumerated as follows: (1) animism, (2) physiological units, (3) heredity as a form of motion or as memory, (4) pangenesis, (5) idioplasm as distinguished from trophoplasm, (6) germ plasm as distinguished from somatic idioplasm, (7) continuity of germ plasm, (8) evolution, and (9) epigenesis. We shall take these up one by one, judge them in the light of the facts and from such as seem valid try to build up for ourselves a theory of heredity and development.

Animism.—The earliest views as to the causes of the phenomena of heredity may generally be classed under the head of animism. Most of them agree that the character of the material body is controlled by a spiritual body, the soul, or *animus,* which enters the material body at its conception.

Van Helmont and other writers of the middle ages have supposed that there is an actual transfer of spiritual substance not only through the sexual products but also through the milk of the mother or nurse. Indeed, it is said that such is the belief of many persons at the present time.

Others believe that the thoughts of the mother may affect the mental and physical character of the developing child. Birth marks, supposed cases of telegony, and the like, have been explained in this way. When Jacob set up the rods before the cattle he was acting upon this theory.

The animistic theories have the great advantage of simplicity, but they are utterly without scientific basis and, therefore, must be rejected.

Physiological Units.—In direct contrast with the animistic theories of heredity are the materialistic theories, —those that postulate a *physical basis* for heredity. One of the earliest attempts to ascribe a physical basis to heredity is that of Buffon. According to his conception, organic matter is essentially different from inorganic matter and the two are equally indestructible. *Organic molecules* are to be found everywhere and are capable of uniting to form an organism wherever they come together under certain conditions, hence his theory of spontaneous generation.

When Herbert Spencer wrote his "Principles of Biology," it was known that there is no chemical element found in living bodies that is not found also in inorganic substances and that Buffon's idea of organic molecules was without foundation. Spencer, however, made a very decided step forward when he revived the idea in another form.

If living material be separated into its constituent chemical molecules it ceases to be alive. Life is not a property of any ordinary chemical substance. Still you can divide living material, and even particles of a cell will retain for a time at least their vital properties. Therefore living matter must be made up of units, much smaller than a cell, and much larger and more complex than a chemical molecule. Spencer calls these ultimate particles of living matter *physiological units.* He regards them as possessing the physical basis of life and as being the bearers of the hereditary qualities.

Haeckel accepts Spencer's theory but refuses to believe that the physiological unit, which he calls a *plastidule,* is anything more than a very complex chemical molecule.

Weismann agrees with Spencer in regarding protoplasm as made up of units which are of a higher order than a molecule. He calls them *biophors* (the life bearers) and attributes to them somewhat different properties from those that Spencer supposes his physiological units to possess. The biophors carry with them only the elementary qualities of the organism. The true bearers of heredity are higher units, the *determinants,* which are themselves composed of biophors having certain properties and arranged in a definite order.

Nägeli takes a somewhat similar position. According to him, when proteids are formed in a watery solution they are precipitated in minute crystal-like masses that he calls *micellæ,* but they do not form part of the living material until they are united into larger masses which are drawn out into threads. These threads of micellæ are the ultimate particle of living matter and the bearers of the hereditary qualities.

Darwin, who was one of the first to give to the world a definite theory of heredity, made no attempt to discover the ultimate structure of living matter. He believed, however, in a physical basis of heredity, which he thought could be found in minute bud-like bodies, *gemmules,* given off from the various cells of the body. He was followed by Brooks and to a certain extent by Galton, and de Vries attempted to improve his theory by supposing the gemmules, which he named *pangenes,* not to be produced by the cell, but by the nucleus.

In all of these theories the bodies that are supposed to carry the hereditary characteristics are too minute for observation, and therefore it is equally impossible to prove or disprove their existence. In fact, these theories are not intended to be anything more than working hypotheses. The main question with us is, not whether one or the other of these hypotheses is correct, but whether the general principle that underlies them all should be accepted or rejected. It seems to the writer that no one who has carefully studied the phenomena of fertilization and development, and has considered the results of heredity, can fail to believe that it has a physical basis and that this must consist of units that are much less than the cell and much more complex than the molecule.

Heredity as a Form of Motion.—The earliest theory of heredity that is sufficiently well founded to deserve serious consideration is that of Herbert Spencer. But even this theory is conceived to a great extent independently of any facts, and is therefore largely metaphysical and to be understood only in connection with Spencer's philosophical system of cosmic evolution.

He compares the organism to a crystal. The molecules which go to make up a crystal are originally all exactly alike, but in the crystal they do not all have the same relative position nor the same morphological value. One will form part of an angle, another part of a face, etc. In a similar way the organism is made up of physiological units that are all alike but differ in position. The molecules of the crystal on the one hand, and the physiological units of the organism on the other, have a certain *polarity* that causes them to unite whenever possible into aggregates having a certain definite form. If a crystal be mutilated and then placed in a saturated solution of the same salt, deposition of new material will take place in such a way as to restore the crystal to its original shape. Spencer regards the regeneration of lost parts in organisms as an exactly analogous process.

The form alike of the crystal and of the organism is due to interaction of internal and external forces. But the organism differs from the crystal in being much more sensitive to external conditions; it is due to them that variations occur. When a permanent variation is produced the polarity of the physiological units has been changed. But any force affecting a part affects the whole and, therefore, the polarity of all the physiological units in the body will be altered, including those of the germ cells. Consequently when the physiological units of the germ grow and multiply to form a new organism, they will tend to arrange themselves, not in the form that the parent had originally, but in the form that it acquired as the results of the action of external conditions. In this way all characteristics, whether congenital or acquired, tend to be inherited. According to this view heredity may be regarded as a form of motion or energy that is propagated from all parts of the body to the germ cells.

The famous botanist, Nägeli, spent the latter years of his life in working out a very complete theory of heredity that in many of its essential features closely resembles Spencer's. The threads of micellæ that, according to Nägeli, constitute the active living material are arranged in bundles which are continuous throughout the body and into the germ cells. Each thread is the seat of one of the fundamental characters of the organism, and all of the different kinds of threads necessary to make a complete organism are present in each bundle. From time to time new threads may arise, causing congenital variations in a certain definite direction. External conditions affect the micellar threads, and their reactions lead to adaptive modifications. These morphogenic stimuli set up by external conditions may be transmitted along the threads to the germ cells with the result that the adaptive modifications of the parent may be inherited by the offspring.

If a stone be dropped into the edge of a pond, the surface of the pond at that point is momentarily altered. This disturbance sets up a wave motion in adjacent particles and these set other particles in motion and so on until the wave finally reaches the farthest shore. Spencer and Nägeli think that in the same way anything that affects the physiological units or micellæ in one part of the organism sets up a sort of wave motion that extends throughout the body and into the germ cells affecting their physiological units so that they may give rise to similar modifications in the offspring. Nägeli makes an improvement on Spencer's theory in furnishing a path for heredity along the micellar threads.

Several other authors have attempted to construct similar theories, but none of them presents any advantage over the ones that have been outlined.

Haeckel's theory is intimately connected with the monistic system of philosophy and is almost entirely metaphysical. The cycle of life from egg to egg is, according to Haeckel, a great wave motion. As each individual gives rise to numerous offspring, this wave motion becomes branched with the act of generation. This branched wave motion is called *perigenesis*—and the *plastidules* of which the living material is composed have a similar wave motion, or perigenesis. Heredity is due to the propagation of this wave motion. Haeckel sums up his theory by saying that heredity is the memory of the plastidules; variability, their power of perception.

Orr has made rather an elaborate attempt to show that heredity is a phenomenon akin to habit. The protoplasm of the parent acquires the habit of growing in a certain way, and when a small piece of this protoplasm is separated to form a child it retains its previously acquired habits, with the result that the child grows in the same way that its parent did. Cope also favored a theory following somewhat these same lines.

The only evidence of importance in favor of these theories is the fact that in certain tissues of animals and plants the cells are found to be connected by minute protoplasmic threads. This line of evidence has been gathered together recently (1898) by O. Hertwig, who calls attention also to the interesting experiments of Pfeffer, which show that in one case at least these protoplasmic filaments may transmit a formative impulse. A vegetable cell deprived of both its nucleus and cellulose wall will not regenerate either, but if the nucleus be present a new cell wall may be formed. Pfeffer prepared cells of the protonema of a moss in such a way that an isolated mass of protoplasm without a nucleus remained connected to its neighboring nucleated cell by the fine protoplasmic filaments traversing the cell wall. In such a case a new cell wall was formed around the protoplasm. But if both cells were deprived of nuclei the cell wall was not regenerated.

On the other hand, there are certainly in the bodies of both animals and plants cells that have no such connections, and a general continuity of protoplasm has not been demonstrated in any organism except in certain algæ and in the earliest stages of cleavage in the eggs of some animals. We cannot tell, of course, what future experiments may bring forth, but there is no evidence at present that any formative impulse may pass from one cell through a series of cells to a distant one, as would be required by the dynamic theories of heredity.

The objection to these theories that occurs to one at once is their fanciful character and lack of any really substantial basis of fact. Their real motive is to account for the supposed inheritance of acquired characters. If any one of these theories is true, then the inheritance of acquired characters should be a matter of every-day occurrence. It is impossible to prove that acquired characters are never inherited and it is therefore impossible to disprove any such theory. But the ablest advocates of the doctrine of the inheritance of acquired characters are admitting now that such inheritance is not common, and, therefore, such a theory cannot be a complete explanation of heredity, but must represent at most only a small factor.

We may conclude, then, that the idea that heredity is a form of motion or something akin to memory cannot be accepted until more evidence in its favor is presented, and such evidence does not seem to be forthcoming.

Pangenesis.—Four years after Spencer published his "Principles of Biology," Darwin gave to the world his provisional hypothesis of "Pangenesis," as the concluding chapters in his book on the "Descent of Man."

The fundamental conception in this hypothesis had been expressed about four hundred years before Christ by the Greek philosopher Democritus when he said that the seed of animals is elaborated by contributions from all parts of the body; and Buffon likewise had supposed that the different parts of the offspring are made up of organic molecules derived from corresponding parts of the parents. But the influence that this conception has had on scientific thought is due to the brilliant manner of its presentation by Darwin.

Darwin supposed that the contributions from the various parts of the body are in the form of *gemmules*, little buds given off from each cell in the body. The gemmules circulate in the blood and are finally collected in the sexual products. When the egg develops each gemmule may give rise to cells like the one from which it was derived. Thus by a simple and perfectly intelligible process Darwin explains the inheritance by the child of the various characteristics of the parent, both congenital and acquired. All of the gemmules in the egg are not supposed to develop, but some may be passed on to subsequent generations. This is always the case with the gemmules representing the sexual characters. Individuals of one sex always contain the gemmules of the other in a latent condition. All cases of reversion are supposed to be due to the development of such latent gemmules. Other forms of variation are explained as due to the rearrangement of the gemmules in the egg, or else as due to the direct action of the environment, or the effects of use and disuse upon the cells of the parent which are transmitted by the gemmules given off from them.

The central fact upon which Darwin's theory is based is the supposed inheritance of acquired characters, but it explains equally well the inheritance of congenital variations, reversion, particulate inheritance, alternation of generation, etc. It is therefore a very complete theory of heredity.

As early as 1872, however, Galton was led to doubt Darwin's theory. He urged his objections in the first place on *a priori* grounds. He did not believe that acquired characters are generally inherited. The gemmules, he said, are purely imaginary, and therefore their existence is an unwarranted assumption. But, waiving this last objection, another and more serious one arises. If we suppose that every cell is continually giving off gemmules, the number present in the organism must be enormous; and, if every cell of the offspring is represented by a gemmule in the germ, we see that if a spermatozoon is to contain not only these gemmules, but also a large number of latent ones, in order that so many may lodge in so small a space, they must be excessively minute.

In the second place, Galton tested the question experimentally. He took silver-gray rabbits, which generally breed true, and into eighteen of these he transfused blood from rabbits of other breeds. He reasoned that, if gemmules be given off, as Darwin supposed, the blood must contain a large number, and, if blood of one breed is transfused into the body of another, the offspring of the latter should show some traces of characters of the former. Eighty-six young were reared from the individuals experimented upon, and none of them showed any trace of foreign blood.

He concluded, therefore, that pangenesis pure and simple is an incorrect hypothesis. He was willing to admit, however, that acquired characters might rarely be inherited and that this might be explained by the occasional giving off of germs by cells.

In 1876 Brooks outlined a theory of heredity which was very fully developed in his book on "Heredity," in 1883. This theory is a modification of Darwin's theory of pangenesis changed to meet the objections of Galton and others. According to Brooks, the phenomena of heredity in the strict sense are due to the *continuity of the germ cells,* a principle that will be discussed later, while variability is explained by pangenesis. Brooks supposes the germ cells to contain gemmules representing all parts of the body. Most of these gemmules are derived from more or less remote ancestors, having been passed on in a latent condition from generation to generation. New gemmules are not being given off all the time by cells of the body, but are produced only by cells which for the time being are subjected to unfavorable conditions. The new gemmules may circulate throughout the body, but in the male the sperm cells constitute a special apparatus for the collection and storing of new gemmules. When fecundation takes place the new gemmules unite with the corresponding ones in the egg and hybrid gemmules are produced which *like any other hybrids* are variable. This causes variability in parts of the offspring which correspond to those subjected to unfavorable conditions in the parent, especially in the father. According to this view, the mother is the conservative element, the father the progressive, or variable element in heredity. External conditions affecting the parent cause variability in the offspring, but not in any particular direction. Acquired characters are not inherited. Brooks brings a strong array of facts and much skill in argument to the support of his theory, but, nevertheless, it is far from convincing. The gemmules of Brooks are just as much products of the imagination as Darwin's, and none of the investigations of cell structure or of cell function has revealed any process analogous to the formation of gemmules.

To sum up, the theory of pangenesis presented in various forms by Darwin and Brooks supposes the germ to be made up of material particles derived from all parts of the parents or more remote ancestors and able by developing to form corresponding parts of the offspring. This theory agrees with the dynamic or memory theories in supposing that the characters of the offspring depend on the character of certain physical substances in the germ, and that the germinal characters in turn are influenced directly by the corresponding parts of the parents. The theories differ in the method by which this influence is supposed to be exerted. According to the dynamic theories homologous parts of the parent and offspring are alike because the germinal rudiments of the parts of the offspring have been subjected to the influence of some sort of formative energy radiating from homologous parts of the parent. According to the theory of pangenesis, homologous parts of the parent and offspring are alike because they are of the same substance (II., Fig. 2607). But these theories are found to be equally unsatisfactory when tested by the light of recent knowledge of the history of the germ cells.

Idioplasm.—The theory of epigenesis is intermediate between the idea of heredity as a form of energy and a third fundamental conception,—*continuity* of the physical basis of heredity. The doctrine of continuity depends upon observations of the structure and history of the germ cells, and involves two other fundamental conceptions in regard to the relations of the parts of the cell. These are the doctrines of *idioplasm* and of *germ plasm.* We owe the first of these ideas to Nägeli. He regards protoplasm as composed of two substances. Both of these consist of proteids in the form of minute rounded micellæ and of water. In one of these substances, the "Nahrplasma" or trophoplasm, the micellæ are scattered through the water without any special arrangement. In the other substance, to which he gave the name *idioplasm,* the micellæ, on the contrary, have a very definite arrangement into threads which in turn are united into bundles.

The idioplasm is the true living substance and all of the characters of the organism are due to its activities. The trophoplasm, on the other hand, is not really alive, but is the nutritive material upon which the idioplasm draws in order to grow and to make good its waste. The threads of micellæ have been mentioned before as being, according to Nägeli, the bearers and conductors of hereditary qualities. These threads constitute the idioplasm.

Weismann adopts Nägeli's conception of the idioplasm with some important modifications. He agrees with De Vries in holding that Nägeli's view that the idioplasm forms a connected network throughout the organism is untenable. According to Weismann, the idioplasm is to be looked for only in the nuclei of the cells. It is in the nucleus that new living material is constructed, and it is from the nucleus that it migrates into the cytoplasm where it is used up in the course of its functional activities,—such as secretion, contraction, and the like. The formation of new material takes place in the nucleus, the functional activities of the cell take place in the cytoplasm; or, in other words, the nucleus is the seat of the anabolic processes, while the cytoplasm is the seat of the katabolic processes. According to this view, then, the cytoplasm is actively alive and not merely a mass of nutritive material, but its character is due to the stamp impressed upon it by the idioplasm within the nucleus. There is considerable evidence in favor of the view that such a division of labor between nucleus and cytoplasm really exists, as will be seen later.

Germ Plasm as Distinguished from Somatic Idioplasm.—Weismann goes a step further and divides idioplasm into two kinds,—somatic idioplasm and germinal idioplasm, or *germ plasm.* It follows as a matter of course that the idioplasm of the germ cells must be capable of bearing the heredity qualities of the organism. It is idioplasm of this kind that Weismann calls germ plasm. He thinks that the somatic cells do not contain germ plasm as a rule, but each cell contains only a certain kind of idioplasm which constituted only a small part of the original germ plasm. Thus muscle cells contain only muscle idioplasm, liver cells only liver idioplasm, ganglion cells only nerve idioplasm, etc. It is differentiated idioplasm of this sort that he calls *somatic* idioplasm.

Many critics of Weismann refuse to accept these distinctions. They say that there is no evidence that there is any real difference between germ plasm and somatic idioplasm. We shall be better able to judge of the merits of this controversy later on. In the mean time we may employ germ plasm as a convenient term to designate the idioplasm of germ cells without implying anything in regard to the somatic idioplasm. Minot goes still further and declares that the whole idea of idioplasm is wrong. That we have no right to say that any part of the cell is more essential to its life than another, that we must regard the life of the cell as the total effect of everything that it contains, whether streaming protoplasm, food particles, products of excretion, or what not, and that the form and functions of the cell depend upon all of these. Minot calls this the theory of panplasm.

In view of these opinions and others that are to follow, it will be interesting at this point to glance at the evidence in favor of the theory that the nucleus is the centre of control for the activities of the cell, and especially of the germ cell.

The Location of the Idioplasm in the Nucleus.—The theory that a part of the protoplasm is differentiated as an idioplasm controlling the destinies of the cell, and that this idioplasm is situated in the nucleus—more especially in the chromatin of the nucleus—rests upon three principal arguments.

In the first place a study of the phenomena of heredity shows that the correlation between parent and offspring is practically equal for both parents (see Table II.). Therefore, if the physical bases of heredity be an idioplasm, it must be contributed to the fertilized ovum in equal proportion by the two parents. Now observations show that the chromatin of the fertilized egg is derived in exactly equal proportions from the two parents, and, moreover, the chromatin is the *only* part that is equally of male and female origin. It was supposed at one time that the centrosomes of the first cleavage spindle (see *Segmentation of the Ovum*) are derived from the centrosomes of both the male and female germ cells. But it has been pretty thoroughly demonstrated in a large number of cases that the centrosome of the ovum disappears at the time of the formation of the female pronucleus (see *Ovum*) and that the centrosomes of the first cleavage spindle are either derived from the spermatozoa only or else arise *de novo*, in the cytoplasm. The centrosome, therefore, cannot be the bearer of the hereditary characteristics. Therefore, if present, the idioplasm must be looked for in the chromatinic element of the nucleus. The evidence upon which this argument is based has been discussed in the article *Chromosome.* (See also *Reduction-division*, *Ovum*, *Spermatozoa*, and *Impregnation.*)

Secondly, it is known that the correlation between homologous parts of parent and offspring is approximately equal for all parts of the body in which the heritage is blended. From this it is evident that physical basis of the hereditary characteristics must be distributed equally from both parents to all parts of the body of the offspring. Now we know that all cells of the body are derived by fission from one single cell, the fertilized ovum. Further, during the first division of the ovum the chromosomes are divided in such a way that the two daughter cells receive chromatin of both male and female origin in exactly the same proportion as found in the fertilized egg; and in each subsequent cell division the chromatin is distributed equally between the daughter cells. Therefore we may infer that under ordinary circumstances the chromatin of every cell in the body is equally of maternal and paternal origin,—provided that it can be shown that the chromosomes maintain their individuality during the so-called resting stage between two cell divisions. It is well known that there is no appearance of such individuality in most resting nuclei. Neverthelesss, as the reader may see by reference to the article *Chromosome,* there is a considerable body of evidence to show that this is only an apparent loss of individuality, and that the chromosomes formed preparatory to division are essentially the same as those present at the end of the previous fission, only grown larger.

Historically, then, the chromatin fulfils all the requirements of the supposed idioplasm. It remains now only to examine the third argument, that the chromatin and the nucleus, which contains it, have a controlling effect more than other parts upon the activities of the cell, especially upon the formation of structures.

As early as 1877 Brandt showed that fragments of a protozoan, if lacking a nucleus, would die quickly, while portions containing nuclear material would heal their wounds and live. These observations have been confirmed and extended by Nussbaum, Gruber, Verworn, Lillie, and others. They find that enucleated fragments of various protozoa may live under favorable conditions for a number of days, or even weeks, and "will perform perfectly normal movements, show the same susceptibility to stimulus, and have the same power of engulfing food as nucleated fragments." "They lack, however, the power of digestion, secretion, and regeneration." In like manner, if a nerve fibre be cut in two the portion connected with the cell containing a nucleus lives and grows, while the distal portion dies and disintegrates. Verworn has found, however, that an isolated nucleus is equally incapable of regeneration, and Lillie has shown that in Stentor a fragment containing a nucleus cannot regenerate its lost parts if the cytoplasm is reduced beyond a certain amount—one-twenty-seventh of the original volume in this case. From this it is evident that the life of the cell depends upon the combined activities of the nucleus and the cytoplasm. Perhaps regeneration is impossible because the means of engulfing food has been destroyed. It does not disprove the theory that the nucleus is the nutritive and dynamic centre of the normal cell, a theory that is supported by several other lines of evidence.

The *position* of the nucleus indicates that it plays an especially important part in the economy of the cell. For example, Haberlandt (1877) showed that in plants the nucleus lies nearest that part of the cell which is undergoing most rapid growth, as in the formation of root hairs, thickening of cell walls, etc.; and Korscheldt (1889) has called attention to the fact that in animal cells the nucleus lies on the side nearest the source of food supply. Changes in the *form* of the nucleus indicate the same thing. In both animals and plants it has been seen that in cells actively forming new material the nucleus becomes enlarged, and sometimes branching. Moreover, an actual *transfer of material* from the nucleus to the cytoplasm has been observed. Hodge found that the nuclei of ganglion cells shrink during functional activity. In cell division all parts of the nucleus except the chromosomes and sometimes parts of the chromatin disappear in the cytoplasm. They may be lost as products of metabolism, but it is probable that part of them remain as permanent structures in the cytoplasm. Upon the formation of a new nucleus after division the nuclear membrane, linin network, and nucleoli are regenerated from the chromatin.

Finally, we have the interesting experiments of Boveri, which, while unfortunately not perfectly conclusive, tend to show the great importance of the nucleus in heredity. He mixed fragments of eggs of one species of sea urchin with spermatozoa of another and obtained dwarf larvæ, presumably by the union of spermatozoa with enucleated egg fragments, and these larvæ possessed purely paternal characteristics.

In the cells of higher plants, there are small protoplasmic bodies called *plastids,* and some of these are the chorophyll bodies and give the color to the plant. Plastids multiply by fission. They are present in the egg cell and are passed on to the daughter cells in cell division. But there are no plastids in the pollen tube so that these structures if they are, as they appear to be, permanent cell organs, are of purely maternal origin. Nevertheless, hybrid plants may exhibit more or less of the color of the male parent, showing that the male component of the nucleus influences the character of these apparently independent plastids.

It is well known that the character of the grain of Indian corn is modified by the kind of pollen that falls upon the stigma. The part affected seems to be of purely maternal origin and this phenomenon, known as xenia, was for a long time an unsolved puzzle. Webber has recently suggested that its explanation is to be found in the discoveries of Guignard and Nawaschin, that in the lily and Fritillaria there is a double fertilization. While one nucleus from the pollen tube unites with the nucleus of the egg cell, a second one from the same source unites with the nucleus of a cell that by its division is to give rise to the main part of the seed. If the same process can be shown to occur in maize, then xenia is explained and the important formative influence of the nucleus is demonstrated, for there is no evidence that any other structure passes from the male plant into the embryo sac.

Continuity.—We are now prepared to consider one of the most important of the fundamental conceptions found in the more recent theories of heredity. The idea is important because it is founded upon the facts of observation which have been outlined in the preceding sections of this article. This is the theory of continuity. Like the theory of pangenesis, it attempts to discover a physical basis for heredity in the germ cells. But it differs from that theory in the view taken as to the history of the bearers of the hereditary qualities, and in regard to the relation of the germ cells to the somatic cells of the parent.

According to the theory of pangenesis, the germ gives rise to an individual like the parent, because the germ is composed of material particles, called gemmules, derived from every part of the parent and capable of reproducing the parts from which they arose (II., Fig. 2607).

In strong contrast with pangenesis is the theory of continuity. According to this theory, the germ gives rise to an individual like the parent, not because any part of the germ is derived from the parent, but because this germ which produces the offspring is a part of the *same* germ that gave rise to the parent (III., Fig. 2607). An egg or a spermatozoon is a cell, and like every other cell is derived from a pre-existing cell by division. If we trace the history of the germ cells in any individual, we find that they have arisen by a succession of cell divisions from the same fertilized eggs that produced the whole body (see *I.*, Fig. 2607). They are the lineal descendants of that egg, and having undergone little or no differentiation they share its qualities. The two germ cells that united to form that egg have had a similar history, and so on back for all generations, and in every case this history is shared by the nucleus and more especially by the chromatin. If we regard the chromatin as the seat of germ plasm, then we have good reason to believe that the germ plasm in every germ cell to-day has been derived by growth and an unbroken series of divisions from germ plasm that existed when germ plasm was first differentiated in organisms living so long ago that even the rocks can tell nothing of their history. According to this view, the successive generations in a family may be compared to a string of pearls in which the cord that holds them can grow at one end and by an annular enlargement and division produce a new pearl one after another. Each pearl would represent the somatic cells (body cells) of an individual and the cord would represent the germ plasm.

Lloyd Morgan has expressed the difference between pangenesis and the continuity of the germ plasm very graphically by saying that by pangenesis the hen produces the egg which in turn gives rise to a new hen, while by continuity of the germ plasm the hen does not produce the egg but the egg produces the hen.

The first to recognize that the germ cells differ from the body cells and are continuous in descent from generation to generation, and that this may serve to explain heredity was Sir Richard Owen, who published this opinion in 1849. Afterward, however, he denied that such an explanation is possible.

The next one to express a similar opinion was Francis Galton, writing in 1872 and 1876. He gave the name "stirp" to the sum total of all hereditary principles, or germs, in the germ cells and, according to his theory, heredity is explained by the multiplication and transmission of this stirp.

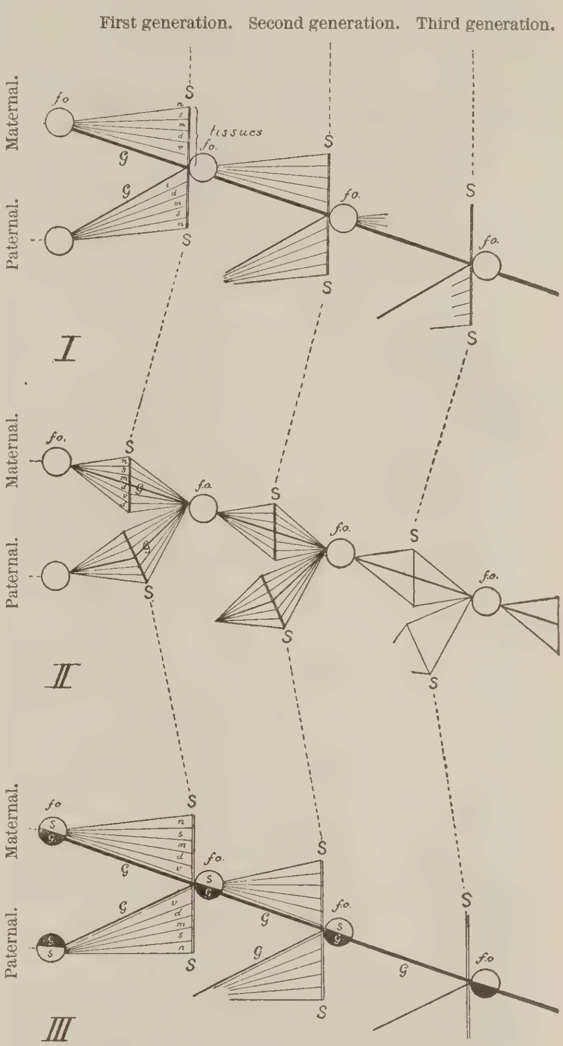

FIG. 2607.—Diagram Illustrating, I. Normal Histogenesis; II. Theory of Pangenesis; III. Theory of Continuity of the Germ Plasm. The fertilized ovum (*f.o.*) by the process of cell division gives rise to the adult body, or soma (*S*), composed of *somatic cells* (*n*, *s*, *m*, *d*, *v*) constituting the nervous, secretory, muscular, digestive, and other tissues, besides the *germ cells* (*G*) of the reproductive organs. I. Histogenesis, showing the successive rise, *G*, and union (*f.o.*) of the maternal and paternal germ cells by direct histogenesis. II. Pangenesis, showing the tissues of the body, *S*, contributory to the germ cells, *G*, so that each *f. o.* is composed of elements, gemmules, from both the somatic and germ cells. III. Continuity of the germ-plasm, showing the division of the idioplasm, *f.o.*, of the egg into somatoplasm, *S*, from which the body cells arise, and germ plasm, *G*, which passes directly to the germ cells establishing a direct continuity.

Brooks outlined his theory of heredity in 1876 and published it in full in 1883. He says: "The ovum is a cell which has gradually acquired a complicated organization and which contains material particles of some kind to correspond to each of the hereditary characteristics of the species. The ovum, like other cells, is able to reproduce its like, and it not only gives rise during its development to the divergent cells of the organism, but also to cells like itself. The ovarian ova of the offspring are these latter cells or their direct unmodified descendants." The child will therefore be like the mother except in so far as it is affected by new gemmules introduced chiefly in the process of fertilization. Here we have the theory of the continuity of the germ cells stated very clearly, but pangenesis is added to it to explain the origin of congenital variations.

The continuity of germ cells had been recognized by Jäger and Nussbaum in 1879 and 1880, but this did not lead in either case to any important generalizations.

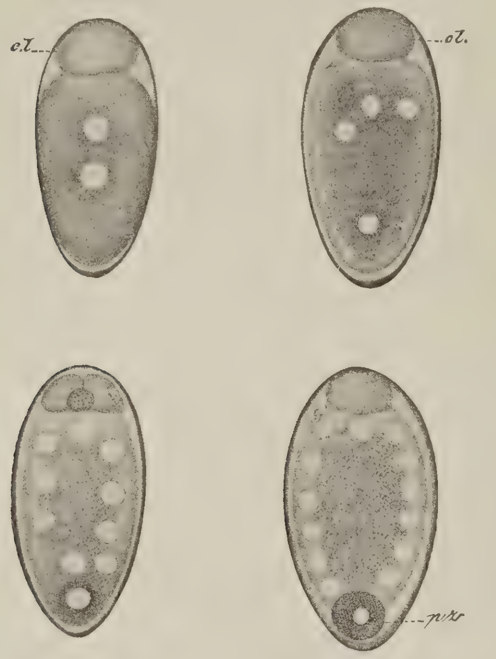

FIG. 2608.—Early Stages in the Development of the Parthenogenetic Egg of the Gall-fly, Cecidomyia. *p.z*, Primary germ cell. (After Meschnikoff.)

From studies on the origin of the germ cells in insects and in hydromedusæ, Weismann arrived at a similar view at about the same time and quite independently, and it is due to his series of brilliant essays, beginning in 1883, that the theory of continuity has taken so important a place in recent discussions.

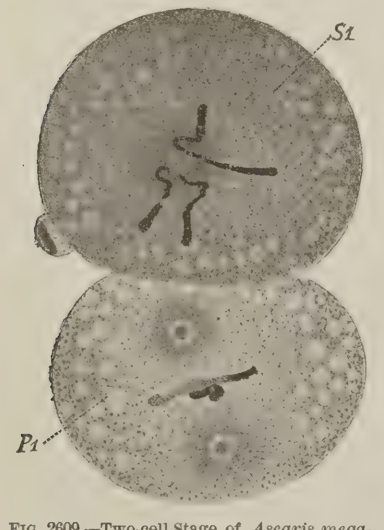

FIG. 2609.—Two-cell Stage of *Ascaris megalocephala* var. *univalens*. *S1*, First somatic cell; *P1*, first cell of the germ tract. Highly magnified. (After Boveri.)

Weismann draws a distinction between continuity of germ cells and continuity of germ plasm. In a few organisms, the germ cells are really continuous. In the Diptera (flies) for example the first cleavage of the egg (Fig. 2608) results in the formation of two nuclei, one of which gives rise to the nuclei of all the germ cells of the embryo and to them only, while the other gives rise to the nuclei of all the somatic cells. A remarkable case of continuity of germ cells has been discovered by Boveri in Ascaris. Figs. 2609 to 2615 represent some of the principal stages illustrated in his beautiful memoir. Fig. 2609 shows the egg in the two-cell stage and both cells, *S1* and *P1*, which are apparently alike, are preparing to divide. In Fig. 2610 the division is farther advanced, and a striking difference is noticeable in the mitotic figures. The chromosomes of the cells *A* and *B*, daughter cells of *S1*, are numerous and very small, and in the plane of division there are some dark bodies composed of chromatin, the rejected ends of the chromosomes of *S1*. These will take no further part in the formation of the nucleus and will finally disappear. On the other hand in *P1*, which we may call the first cell of the *germ tract*, using Weismann's terminology, there are only two large chromosomes moving toward each pole to form the daughter nuclei. *A* and *B* are purely somatic cells. Of the daughter cells of *P1*, one is likewise a purely somatic cell, and when it divides the chromosomes undergo the same transformation that has been observed in *S1*. The other daughter cell is *P2*, the second cell of the germ tract. This is seen preparing for division in the dorsal view of the six-cell stage, Fig. 2611. The two large chromosomes have been reformed. This cell behaves exactly as *P1* did, giving rise to a somatic cell and to the

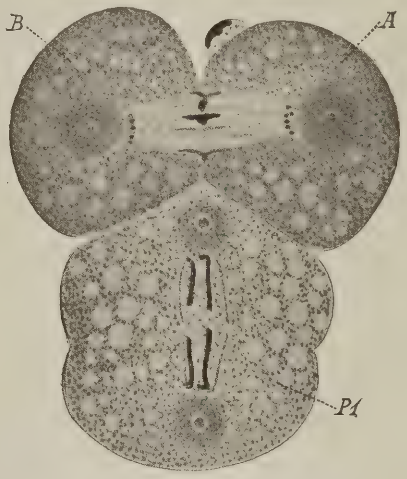

FIG. 2610.—Same. Second Cleavage. *S1* is dividing into *A* and *B*; *P1*, is also in process of division. Note difference in size and number of chromosomes.

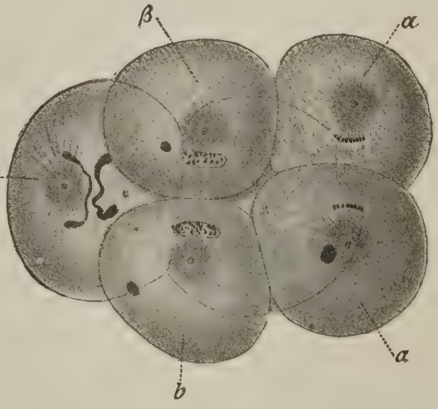

FIG. 2611.—Same. Six-cell Stage. *P2*, Second cell of germ tract. *b*, *β*, Daughter cells of *B*; *a*, *α*, daughter cells of *A*.

third cell of the germ tract, *P3*, Fig. 2612. This cell divides again in the same manner, producing *D* and *P4*, Fig. 2613, and one of the daughter cells of *P4* is *P5*, Fig. 2614, which in turn produces the two priordial germ cells *UGI* and *UGII*, Fig. 2615. Thus the remarkable difference between the nuclei of the germ cells and the somatic cells in this form has enabled Boveri to trace every stage in the genealogy of the germ cells and their nuclei back to the fertilized egg.

In most animals, however, the cells which arise by the cleavage of the ovum appear to be somatic cells, some of which after a greater or less number of divisions give rise to germ cells. In the plants and plant-like animals, such as the Hydroids, we have extreme cases in which there is no trace of recognizable germ cells until we reach the end of a series of several generations of asexually produced individuals. Such being the fact, how are we to explain heredity? There are two possible explanations, according to Weismann. Either the somatic idioplasm in certain cells is reconverted into germ plasm, or else cells in a certain series contain two kinds of idioplasm: their own peculiar somatic idioplasm that controls their activities, and also germ plasm in a latent condition, which is a part of the original germ plasm of the egg. Weissman holds to the latter view. He believes that at the time of the first cleavage of the egg its germ plasm divides into two similar parts. One of these becomes converted into active somatic idioplasm to form the embryo, the other remains latent and is passed on in this condition to certain cells which become the germ cells for the production of the next generation, as represented schematically at *III.*, in Fig. 2607. In some cases, as in the Hydroids, these germ cells are differentiated, according to Weismann, from ordinary somatic cells. Nevertheless, these cells, like all other cells of the body, have arisen by an unbroken series of cell divisions from the cleavage of the original egg. Therefore, while it is shown that in most cases the germ cells are not really continuous as such, we can suppose that there is perfect continuity of germ plasm. Weismann has invented the name "*germ tract*" to designate the series of cells which forms the line of descent from the egg to the germ cells of the embryo and which may be supposed to contain the germ plasm, for example, *P1* to *P5*, Figs. 2609 to 2615. In the Diptera, Fig. 2608, the germ tract is very short. There is practically none at all, for the primary germ cell is formed at the first cleavage. In Ascaris, as we have seen, it runs through five generations of cells. In the Daphnidæ the germ cells are separated off, likewise, during the early stages of cleavage. In Sagitta this takes place in the gastrula stage. In the Annelids and Molluscs, the germ tract is longer, but may be traced through a relatively small number of very definite cell divisions.

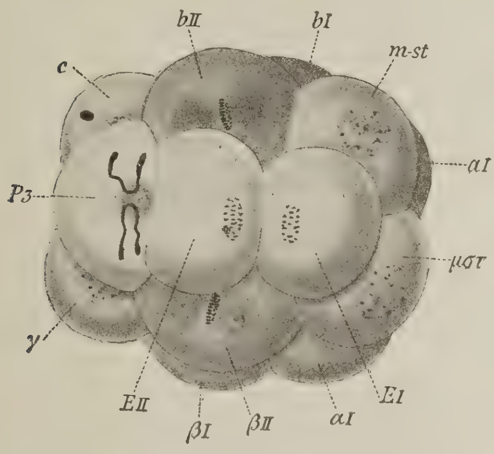

FIG. 2612.—Same. Fifteen-cell Stage. *P3*, Third cell of germ tract.

In the vertebrates there is a large number of cell divisions between the cleavage of the egg and the appearance of germ cells in the embryo. Still they appear early, within the first half of embryonic life at most. Finally we come to the plants and the Hydroids where the germ tract is very long, extending through several generations of asexual individuals. Thus if we studied a sufficient number of species we should probably find all grades from the condition of the Diptera to that of the Hydroids.

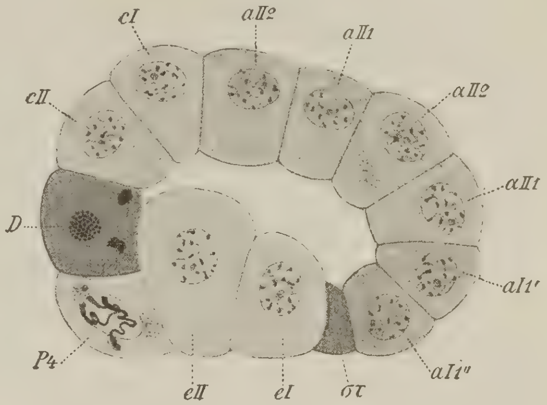

FIG. 2613.—Same. Optical Longitudinal Section of a Blastula. *P4*, Fourth cell of germ tract.

The distinction between somatic idioplasm and germ plasm is upheld by the fact that, except perhaps in rare cases, cells outside of the germ tracts are incapable of becoming differentiated into germ cells. If the gonads (ovary or testis) of any of the higher animals be removed, germ cells never reappear. In this connection there is an interesting experiment published by F. Braem in 1893. The subject was a large female polychæte of the genus Ophryotrocha with ripe eggs and having thirty-five segments bearing parapodia. The animal was cut in two. At the end of three weeks the anterior part had regenerated seven segments bearing parapodia. It was then killed and cut into serial sections and no trace of germ cells could be found in the regenerated part. Evidently here is a difference between somatic cells and germ cells in the powers of regeneration. Of course germ cells might have appeared later, but in the annelids the germ cells are restricted to certain areas of the peritoneum, and it is probable that in this case the wound did not pass

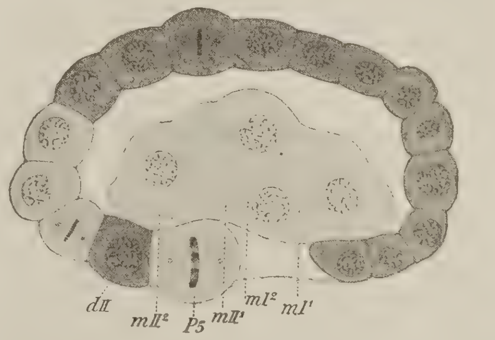

FIG. 2614.—Similar Section of Embryo in the Gastrula Stage. *P5*, Fifth cell of germ tract undergoing division to form the primordial germ cells *UGI* and *UGII*, Fig. 2615. The cell to the left of *dII* is a somatic cell in the same stage of division.

through one of these areas. So it is probable that the germ cells did not receive the same stimulus to growth that affected the other tissues and that therefore no part of the germ tract was included in the regenerated part.

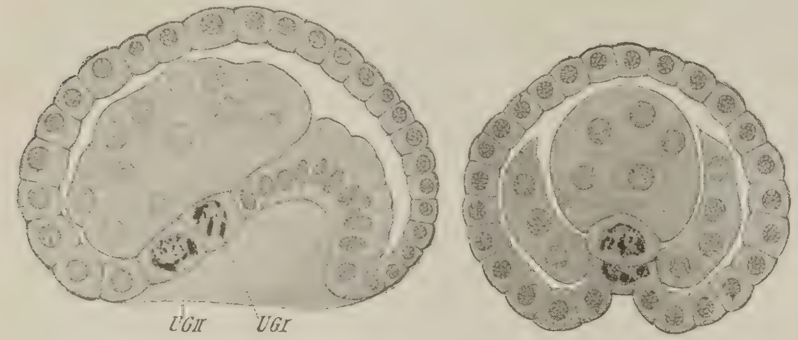

FIG. 2615.—Longitudinal and Transverse Sections of an Older Embryo. *UGI, UGII,* Primordial germ cells beginning to retreat into the interior of the body. (Figs. 2609 to 2615 after Boveri.)

According to Weismann, the best evidence in favor of the existence of distinct germ tracts is afforded by the history of the germ cells of the Hydromedusæ. It is needless to repeat his rather complex argument here, for much better evidence has been furnished recently by Boveri in the history of the germ cells of Ascaris, of which an outline has just been given. The fact of especial importance from Weismann's point of view is the difference between the nuclei of somatic and germ cells; compare, for example, the nuclei of the primordial germ cells, *UGI* and *UGII,* with the nuclei of the somatic cells in Fig. 2615. The origin of this difference may be seen in the two- and four-cell stages, Figs. 2609 and 2610. In the first somatic cell, *S1,* the ends of the large chromosomes are thrown off into the cytoplasm and finally disappear, while the middle part of each chromosome divides transversely into small segments, which behave like ordinary chromosomes in cell division, give rise to small round nuclei, and reappear in subsequent generations of the somatic cells. On the other hand, the large chromosomes of the cells of the germ tract, *P1* to *P5,* behave exactly like the chromosomes of the fertilized egg and give rise to large-lobed nuclei rich in chromatin. "Through this remarkable process," as Wilson remarks, "it comes to pass that in this animal only the germ cells receive the *sum total of the egg chromatin handed down from the parent.* All the *somatic cells contain only a portion of the original germ substance.* The original nuclear constitution of the fertilized egg is transmitted, as if by a law of primogeniture, only to one daughter cell, and by this again to one, and so on; while in the other daughter cells the chromatin in part degenerates, in part is transformed, so that all of the descendants of these side branches receive small reduced nuclei." Wilson adds that it would be difficult to overestimate the importance of this discovery.

All of the evidence goes to show that there is some kind of continuity between the germ cells of one generation and those of the next. The earlier investigators said, "This is a continuity of germ cells." Then came Weismann, who said, "Hold on, you are trying to prove too much. Continuity of germ cells is very rare. Ordinarily the egg gives rise entirely to somatic cells, and then some of these somatic cells give rise to germ cells. But the germ plasm is continuous for it is passed along by the somatic cells of the germ tract until it is finally separated out in the new germ cells. This is proven by the fact that germ cells cannot be produced except by cells of the germ tract." Now come various critics of Weismann and say: "This idea that the cells of the germ tract contain two kinds of idioplasm is a pure assumption that is not warranted by the facts"; and they present a good deal of evidence to show that there is no real difference between somatoplasm and germ plasm. They might add that in the case of the germ tract this distinction is unnecessary, because in every group, not excepting the Hydroids, these cells remain in a more or less undifferentiated embryonic condition. Even if they do form part of the lining of the body cavity or some other organ, the cells which give rise to germ cells have never been highly differentiated as somatic cells. If a muscle cell could by division produce a germ cell, we might be forced to assume that it originally contained two kinds of idioplasm. But there is no reason why the cells which usually produce germ cells should contain anything but germ plasm, for they are not as a rule differentiated in any other direction.

It would seem then that Weismann has been trying to draw too fine distinctions and we must fall back upon the observed facts. These are that the germ cells produced by any individual are derived by growth and fission from the fertilized egg that produced that individual. There is strong evidence to show that the chromatin is the seat of the controlling power in the cell and that the individuality of the chromosomes is maintained during successive mitoses. If this be true, then it is an important fact that the chromosomes in each germ cell are derived by growth and precisely equal fission from the chromosomes of the fertilized egg that produced the individual containing them. I believe that these observations must stand as facts and that they form the only safe foundation for a theory of heredity.

Preformation and Evolution.—The theory of continuity postulates that the child and its parent are alike because both of them have been produced by the same germinal substance. This is a satisfactory explanation of heredity so far as it goes, but it leaves unanswered two large questions, How is variability introduced? and How is differentiation brought about? An attempt to answer these questions involves us at once in the old controversy of Evolution *vs.* Epigenesis (see *Evolution*).

The observations of Wolff, von Baer, and their successors settled this controversy forever so far as the visible phenomena of development are concerned, but the question acquired a new meaning with the advent of scientific speculation on heredity.

Darwin's theory of heredity was the first one in which the theory of preformation was clearly stated. He regarded the egg as made up of gemmules, each one of which is capable of growing and producing one or more cells of a certain definite part of the body. Differentiation is merely the development of the different kinds of gemmules. Congenital variations are due to the transmission from the parent of gemmules having new qualities. Every part of the embryo is represented in the egg by one or more gemmules. The embryo is, therefore, just as much preformed in the egg as it was according to the views of Bonnet a century earlier.

Brooks differs from Darwin in his theory of the origin of the gemmules and of the kind of variability that they produce, but he fully agrees with him as to their function in development. He regards a theory of preformation as the only kind of theory of development that can be defended.

Before Brooks published his theory Wilhelm His, in 1875, presented a theory which has had considerable influence upon subsequent thought. He did not attempt a complete theory of heredity, but aimed to explain only development and differentiation. He rejected the hypothesis of gemmules and relied upon two principles: (1) the principle of differentiation of areas (Princip der organbildenden Keimbezirke), and (2) the principle of unequal growth. He had in mind an egg like that of any of the higher vertebrates, in which the embryo is formed in what is practically a flat blastoderm (see *Area embryonalis*). According to his views the embryo is mapped out at first upon the surface of the egg, each organ and part of organ being represented by a certain area (differentiation of areas). These different areas of the egg differ from one another in density, viscosity, chemical composition, etc., and therefore, when growth begins, it occurs at different times and to different degrees in the different parts. This unequal growth results in the well-known processes of folding, invagination, and the like.

The principle of unequal growth is now universally accepted as one of the fundamental principles of modern embryology. So far as it goes it is undoubtedly a correct theory of development, but we still want to know what causes this inequality. It is due, according to His, to the differentiation of areas; but he does not explain how they arise, and their existence in the unsegmented egg is, to say the least, not self-evident.

Development, according to His, is clearly a process of evolution. In 1888 Roux published the results of some experiments on frogs' eggs that would seem to demonstrate the truth of the principle of differentiation of areas, or germinal localization, as Wilson calls it. By puncturing one blastomere in the two-cell stage he could kill the blastomere operated upon without affecting the other. The result of the operation was that, while the injured blastomere remained inactive, the uninjured one developed into a complete half embryo. Apparently the right and left halves are predetermined in the egg before it divides.

But in the mean time Nägeli had published his idioplasm theory, and various observations upon the functions of the nucleus in fertilization and development had made it seem probable that the idioplasm should be looked for in the chromatin of the nucleus. Roux, therefore, did not look for the predetermination of the two halves of the embryo in the cytoplasm of the egg, as His would have done, but sought for it in the nucleus. In fact, he had five years before these experiments presented the important idea that the chromatin may divide in two ways. It may undergo a *quantitative* division which results in *growth*, by division of the cell into two similar cells, or it may suffer a *qualitative* division, which results in differentiation by the division of the cell into two dissimilar cells. The first cleavage of a frog's egg would be, accordingly, a qualitative division separating the idioplasm of the right side from that of the left.

De Vries in 1889 seemed to help the theory of preformation by supplying a reasonable hypothesis to account for the control of the cell by the nucleus. Although he calls his theory "intracellular pangenesis," it has very little resemblance to Darwin's theory. According to de Vries, the idioplasm has the same composition in all the cells of the body. It is composed of minute particles called *pangenes*, each one of which, like a micellar thread of Nägeli, represents one of the elementary qualities of the organism. The pangenes in the nucleus are in an inactive, or latent, condition and only a few pangenes of each of the many kinds are to be found there. The cytoplasm is made up likewise of pangenes surrounded by a nutritive fluid. But, unlike the nucleus, the cytoplasm contains a great number of pangenes of only a few kinds, and they are all in an active condition. From time to time a pangene in the nucleus will divide. One half remains in the nucleus, the other half migrates into the cytoplasm, where it may undergo repeated divisions. In this way the nucleus controls the cell, while at the same time its idioplasm remains unchanged. Differentiation is brought about by different kinds of pangenes becoming active in different cells.

De Vries argues that various hereditary qualities must be represented by separate material factors, because these qualities may vary independently of one another. It may be supposed that the nucleus controls the cell by liberating some form of energy which acts as a stimulus. But this implies something in the cytoplasm having definite vital properties to receive the stimulus. Or it may be thought that the nucleus secretes a ferment, but this again implies something in the cytoplasm for the ferment to act upon. This something in the cytoplasm requires to be explained, and de Vries concludes that the only tenable hypothesis is that the control of the cell by the nucleus is exercised, not through any power of stimulation nor by means of a ferment, but through the migration of particles of the nucleus into the cytoplasm, of which they then form a part.

We come now to a theory of heredity where the theory of evolution, or preformation, is carried to its ultimate conclusion. This is the theory of Weismann, which has for its basis the hypothesis of the continuity of the germ plasm with the total denial of any inheritance of acquired characters. Superimposed upon this is the idioplasm theory of Nägeli, the theory of qualitative cell-divisions of Roux, and the theory of intracellular migration of pangenes of de Vries.

As has been stated before, heredity pure and simple is explained by Weismann as due solely to the continuity of the germ plasm, some of which is held in reserve in each individual and is passed on to the next generation without receiving any formed material from the somatic idioplasm. We use the term *formed* material, for, of course, the germ plasm receives nutriment just as do all other living parts of the body, and it utilizes this in growth. Weismann rejects entirely both the dynamical and the pangenesis theories of heredity.

According to this view strictly new congenital characters can arise only by the modifying influence of external conditions acting directly upon the germ plasm. External conditions which may affect the germ plasm in this way are food, temperature, and perhaps chemical composition of the surrounding medium. Any change in these factors of the environment may affect the germ plasm within an individual and result in the appearance of a new character in its offspring. The appearance of really new characters, however, is rare. Most variation is brought about by new combinations of old characters, just as any number of new words may be constructed from the twenty-six letters of the alphabet, and innumerable combinations of this kind are produced according to Weismann by sexual reproduction.

The process of fertilization results in the bringing together of two masses of germ plasm having slightly different histories, and, therefore, slightly different qualities. This mingling of two germ plasms is called by Weismann the process of *amphimixis*. In this process the two germ plasms do not fuse, for if they did the child would always have the average character of its parents. As a matter of fact this is a rare occurrence; the individual child is more apt to resemble one parent or a grandparent. We must suppose, therefore, that the germ plasms derived from each parent remain as distinct units in the child, and Weismann calls each one of these units an *id*. If there existed an animal in which sexual reproduction had never taken place its germ plasm would consist of a single *id*. That such units do exist in all organisms now living is shown, according to Weismann, by the presence of a special device for preventing the doubling of the ids that would otherwise occur with each sexual act. This is the reducing division that always precedes fertilization (see *Reduction-division*).

Weismann does not think that the chromosomes are the ids, which of course lie within the nucleus, but he thinks that the small granules of which they are sometimes seen to be composed may be the ids, and therefore he would substitute the word *idant* for chromosome. Each idant of the germ cell he regards as composed of a large number of ancestral germ plasms, or ids, any one of which is capable of directing the entire development of the organism.

Now each id cannot be a homogeneous unit, for we find that a child may resemble one parent in some particular, the other parent in another particular, and perhaps a grandparent in a third, and connected with this there is frequently a lack of correlation so that not only different parts of the adult but different stages in its ontogeny may be independently variable. As Galton puts it, inheritance is particulate. Each id must therefore contain at least as many smaller units as there are independently variable parts in the organism. Weismann calls these units *determinants.* The id, then, has a certain structure. It is composed of determinants that are arranged in such a definite way in relation to one another that they give rise to an organism of their species. Each determinant may control a single cell or a large number of cells if they all vary together.

But a cell may vary in part and not as a whole. Moreover, the determinant must be supposed to reside in the nucleus and its control over the cell must be accounted for. The determinant must, therefore, be composed of still smaller units which are able to pass out from the nucleus and become a part of the cytoplasm, like the pangenes of de Vries. Weismann points out that we must not regard protoplasm as a chemical substance composed simply of atoms and molecules, for no chemical molecule has the power of assimilation and growth. We have to suppose the living material to be a structural combination of dissimilar molecules. These molecules must be arranged in groups, thus forming units of protoplasm which have the power of assimilation, growth, and multiplication by division, but which if further divided would be separated into their constituent molecules and would then cease to be living matter. These units Weismann calls *biophors.* He insists that their existence is not a mere assumption, but that they must exist. All living material is composed of them, and he asserts that the nucleus exerts its control over the cell body by means of the biophors, which pass through the nuclear membrane and become a part of the cytoplasm, like the pangenes of de Vries. Each determinant, therefore, must be composed of a large number of biophors, and when the part that it controls, its *determinate,* presents a differentiation of parts, it must contain a different kind of biophor for each part.

This, then, is Weismann's conception of the structure of the germ plasm. We can understand now from his point of view how ontogeny would take place. Suppose a species where reproduction had always taken place by means of an unfertilized egg, the simplest possible case, then the germ plasm would consist of a single id containing one determinant for each independently variable quality of the species, and each determinant would contain at least as many biophors as there are distinct parts in its determinate. Now before cleavage begins each determinant divides into two, and one set of determinants forms an id of reserve germ plasm, which is to be handed on to the future offspring; while the other forms the idioplasm for the developing organism. The first stage in development is the rapid growth of one determinant of the active id. This is followed by its division into its constituent biophors, which migrate out of the nucleus into the cytoplasm of the egg and cause it to divide into the first two blastomeres. With the division of the cell, the id and its determinants likewise divide, so that each cell contains an id, but this is no longer an id of germ plasm but an id of somatic idioplasm, for it has been changed by the loss of the determinant that was used up to cause the first division. At least one cell, however, (corresponding to the cell *P1* in Ascaris, Fig. 2609) will contain, besides its own particular id of active idioplasm, also an id of inactive reserve germ plasm. Ontogeny thus proceeds by the orderly division of the determinants and the separation of their biophors. In the course of ontogeny two kinds of cell division will occur. In one the daughter cells will have the same hereditary qualities; in the other they will be unlike. In the first, the division of the id is preceded by the division of each determinant into two; in the second, there is no division of the determinants, but they become separated into two sets, one of which goes to form each new id. Thus at the first cleavage one nucleus may contain all the determinants for the ectoderm and the other all of those for the endoderm, or one may contain all determinants for the right side of the body and the other for the left. When ontogeny is completed the idioplasm of each cell contains but a single determinant, which continues to control the cell by sending fresh biophors into the cytoplasm to replace those that are used up in performing their functions. In addition to this, each cell in the germ tract contains a complete id of reserve germ plasm, which remains inactive or simply grows without influencing the cell which contains it.

Now probably in the history of all living organisms sexual reproduction has occurred during innumerable generations. The germ plasm would therefore consist not of a single id, but of a great many. Each one of these would behave in ontogeny, however, just as we have supposed the single one to act.

Now we can see how sexual reproduction aids variation. When there was but a single id of germ plasm, congenital variations could arise only by the slowly modifying influence of external conditions upon its biophors and determinants; but with sexual reproduction we have brought together a number of ids differing slightly in hereditary qualities and each trying to control the development, the result will bring about variation.

The determinants in the various ids will be related in two ways. Those determinants are homologous that control homologous parts of the body, and homologous determinants may again be either homodynamous or heterodynamous to one another, according as they have the property of impressing the same or a different quality upon the part that they control.

When the homologous determinants of the two parents are homodynamous, the offspring will possess the quality that they control in a greater degree than either parent. When they are heterodynamous there will be a struggle between the determinants and the quality in the offspring will be dependent upon the relative strength or numbers of the two sets. All of the determinants from one parent are not likely to have the same relative strength, and hence it is that the child generally resembles one parent in some peculiarities and the other one in others.

If we accept this theory of the structure of the germ plasm, it is easy to explain all of the phenomena of heredity and development.

Variation in the protozoa is due to the direct effect of the environment and to amphimixis. The metazoa and higher plants inherit their fundamental characters from their protozoan ancestors. New characters have been added to these by direct action of environment upon the germ plasm; but the most usual cause of variation is the formation of new combinations of old characters as a result of amphimixis.

Reversion in hybrids is due to the extrusion of ids of one line of descent in the reducing divisions during the formation of ripe germ cells. In pure races it is due to ids acquiring new strength and thus becoming the more powerful after a latent period.

Sexual dimorphism is due to the doubling of the determinants for the sexual character in each id.

Regeneration of lost parts is produced by special determinants in the germ plasm, and reproduction by fission is due to a higher specialization of the same process.

Budding is explained as the result of a doubling of the ids of germ plasm and the distribution of parts of the reserve germ plasm to the somatic cells from which the buds arise.

Alternation of generations is accounted for by supposing each reproductive cell to contain two kinds of germ plasm, one of which becomes active in each alternate generation.

According to this theory every peculiarity of the organism in every stage of its development is represented by a distinct and definitely located structural element in the germ plasm. Development is an evolution, a becoming visible of pre-existing potentialities.

On its face it is a very satisfactory theory, but we shall find that when tested by experiment it fails in many parts.

Epigenesis.—As was noted at the beginning of the preceding section, if we start with the idea of continuity of idioplasm as the basis for a theory of heredity, we soon find ourselves involved in the question as to whether development and differentiation are due to preformation and a process of evolution or are due to a process of epigenesis. Just as we may take Weismann as the champion of the preformation theory, so may we take Oscar Hertwig as the champion of the more extreme side of the theory of epigenesis. His position is supported to a greater or less degree by de Vries, Driesch, and E. B. Wilson.

Hertwig agrees with Weismann in regarding heredity as being due to a continuity of germinal idioplasm which resides in the nucleus and controls the activities of the cell by migrating out of the nucleus into the cell body and there becoming part of the active cytoplasm. Like Weismann he supposes the idioplasm to be made up of minute structural elements which have the power of assimilation, growth, and reproduction by fission; but he differs from Weismann in regard to their other qualities. He calls these bodies *idioblasts* and they correspond in general to Weismann's biophors, to de Vries's pangenes, and to Nägeli's micellar threads.

According to Weismann, the germ plasm is made up of determinants that represent every part of the body that may vary independently, whether this be made up of one cell or of a group of cells. According to Hertwig, on the other hand, the germ plasm is made up of idioblasts that represent only cell characters. All of the different cellular structures that may occur anywhere in the organism may be represented by separate idioblasts in the germ plasm, but characteristics that depend upon combinations of cells cannot be represented there. The egg and the spermatozoon are cells formed by fission from pre-existing cells, and the fertilized egg is likewise a cell capable by division of giving rise to a colony of cells. An egg may contain elements representing nerve fibre, muscle fibrillæ, and the like, because these structures may occur within a cell; but it cannot contain elements representing a hair or a biceps muscle; for hair and muscle are formed only by the union of many cells, and it is impossible to suppose that characters which can be formed only by the union of many cells may be represented in the structure of a single cell. Nevertheless, Hertwig agrees that the characteristics of the adult depend fundamentally upon the structure of the idioplasm in the fertilized egg from which it springs. He compares the organism to a *state*. If we suppose a community or a state to be composed of the offspring of a single pair, the schools, the markets, the courts of justice, and all departments of the government will be the result of the character of that first man and woman, and yet it would be absurd to suppose that these institutions were present in them in a latent condition. Just as all the characteristics of such a state will be the necessary result of the human nature of the man and woman from which it has descended, so all characteristics of the organism are ultimately due to the cell nature of the fertilized egg from which it has developed. We find Hertwig, therefore, opposing two of Weismann's fundamental conceptions, viz., *preformation* and the *qualitative* division of the idioplasm, and it would be well to make a digression here to test these ideas by the results of experiment.

Let us take up first the facts of normal development. According to Roux's theory of qualitative divisions, which is one of the fundamental conceptions of Weismann's theory, the egg is at first *isotropic*, that is, there is no predelineation of the embryo or of its planes of symmetry in the cytoplasm. But when cleavage begins, the qualitative divisions of the idioplasm have the result that the embryo becomes a mosaic made up of cells having different qualities and capable of giving rise only to certain definite parts of the definitive organism. This is called the mosaic theory of development.

As already pointed out, Roux found evidence for his theory in his experiments on frogs' eggs. Since then other evidence has been produced. Crompton experimenting on the eggs of a marine gasteropod (Ilyanassa) found that isolated blastomeres from embryos in the two-cell or four-cell stage (Fig. 2616), "exhibit a typical partial development; that is, each one develops as if the missing portions of the embryo were present. No regeneration of the missing parts takes place." This bears out what we are led to expect from a study of the normal cleavage of the gasteropods and annelids, two large groups in which the method of cleavage is almost identical. The division of the egg in these groups follows a complex but very definite plan. Wilson found that in Nereis every cell division follows a prescribed order up to the fifty-eight-cell stage. At that stage the chief organs of the body are represented by separate cells. Similar results have been obtained by later investigators working upon the development of other annelids and on molluscs. Conklin has traced the cell lineage in Crepidula to the one hundred and nine-cell stage (Fig. 2617). The cells appear in such definite and similar succession in the various species that each cell has been given a distinctive designation, and the history of each cell division has been traced to the time when the principal organs are outlined. In such a form the embryo is really "a visible mosaic work, not one ideally conceived by a mental projection of the adult characteristics back upon the cleavage stages." There can be no doubt about the truth of these observations, and if they constituted all of the evidence, Roux's theory of qualitative divisions and of the mosaic character of the embryo would be fully verified.

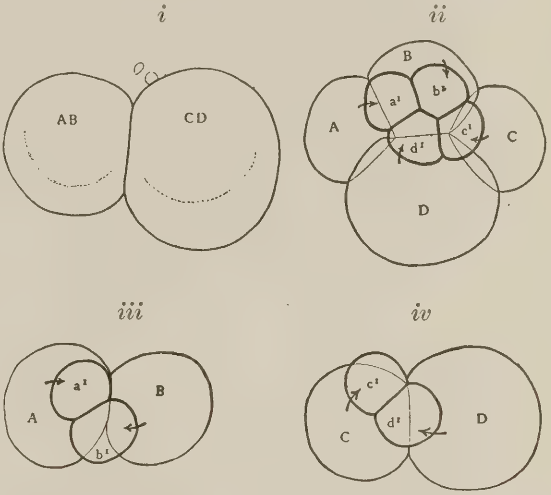

FIG. 2616.—Early Stages in the Development of the Marine Gasteropod, Ilyanassa. *i*, Normal two-cell stage; *ii.*, normal eight-cell stage; *iii.*, half eight-cell stage developed from the smaller isolated blastomere, *AB*; *iv.*, half eight-cell stage developed from the larger isolated blastomere, *C D*. × 112. (After Crampton.)

Unfortunately for the theory, however, there is a great mass of evidence to show that these observations must be interpreted differently.

Beginning with the phenomena of normal development, observations of Miss Clapp on toad fish, and of Morgan on other Teleosts and on frogs show that there is no constant relation between the first cleavage plane and any plane of the adult body. Observations of H. V. Wilson on the sea bass, of Jordan on Amphibia, and of E. B. Wilson on Amphioxus show that there may be considerable variation in the process of cleavage and yet normal embryos will result. E. B. Wilson found three types of cleavage in Amphioxus, a radial form, a spiral form, and a bilateral form, with all grades between, and all of these are equally capable of producing normal larvæ.

These cases are enough to prove that the mosaic theory is not universally applicable, and there is experimental evidence that is still more convincing.

Driesch was the first to experiment with segmenting eggs under *pressure.* Ordinarily in the sixteen-cell stage of an echinoderm egg the cells are separated by alternate vertical and horizontal planes. Driesch found that if the fertilized egg were compressed between glass plates cleavage would take place, but all the planes would be vertical, so that at the end of the sixteen-cell stage the embryo would consist of a one-layered plate of cells. Relations of the nuclei in such an embryo would be very different from the normal, yet if the pressure were now released the embryo would develop into a perfect larva.

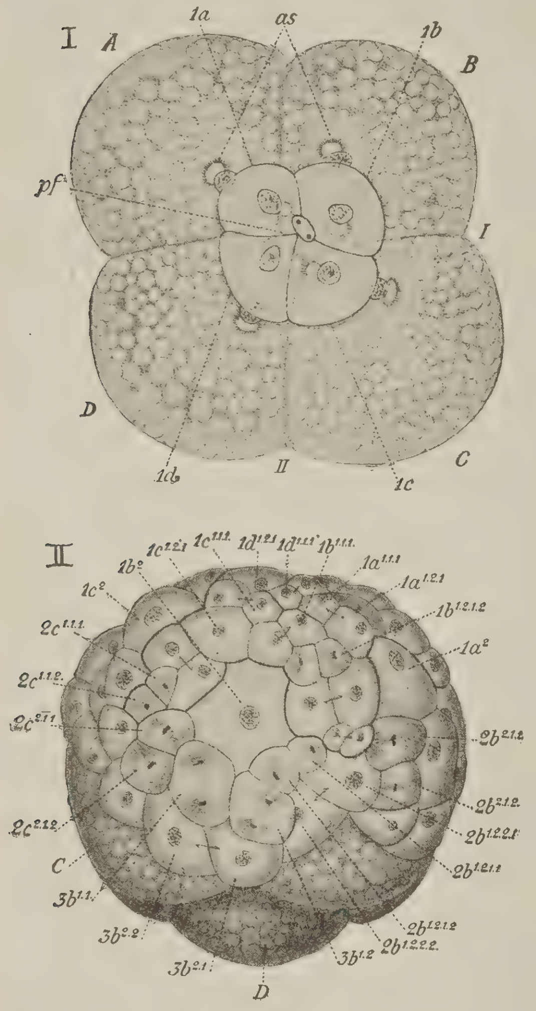

FIG. 2617.—Two Stages Illustrating the Mosaic-like Cleavage of a Mollusc, Crepidula. *I.*, Eight-cell stage; *II.*, stage with one hundred and nine cells. Highly magnified. (After Conklin.)

Hertwig obtained the same results from experiments on frogs' eggs. These are of more interest because of the early differentiation of the egg into micromeres and macromeres. Hertwig obtained a different mode of cleavage, according as he compressed the eggs between horizontal or vertical plates, and both of these forms were found to differ very greatly from the normal, cells becoming macromeres which should normally be micromeres and *vice versa.* Yet upon pressure being removed, all developed into normal embryos.

The most interesting experiments in this line are a few performed by E. B. Wilson on fertilized eggs of Nereis (Fig. 2618). They are especially interesting because of the great definiteness of the cleavage in Nereis and because of the results that Crampton obtained from the isolation of the blastomeres of Ilyanassa. Under pressure beneath a cover-glass, the eggs would divide, each forming a flat plate consisting of a single layer of eight cells. "If they are now released from the pressure, each of the cells divides in a plane approximately horizontal, a smaller granular micromere being formed above, leaving below a larger clear macromere in which the oil drops remain. The sixteen-cell stage, therefore, consists of eight deutoplasm-laden macromeres and eight protoplasmic micromeres (instead of four macromeres and twelve micromeres, as in the usual development). These embryos developed into free-swimming trochophores containing eight instead of four macromeres, which have the typical clear protoplasm containing oil drops. In this case there can be no doubt whatever that four of the entroblastic nuclei were normally destined for the first quartet of micromeres (ectoblast) from which arise the apical ganglia and prototroch. Under the conditions of the experiment, however, they have given rise to the nuclei of cells which differ in no wise from the other endoderm cells. The immediate cause of differentiation must therefore be sought not in the distribution of the nuclei or their mode of division, but in the conditions existing in the cytoplasm."

This conclusion is borne out by the converse experiments performed by Morgan upon the egg of Fundulus. In this minnow, as in other fishes, the blastoderm in the eight-cell stage consists of a single layer of cells lying on one side of the yolk. Morgan discovered that by pricking a fertilized egg so that part of the yolk escaped, he could apparently reduce the pressure on the germinal disc, which would become rounded and would divide so

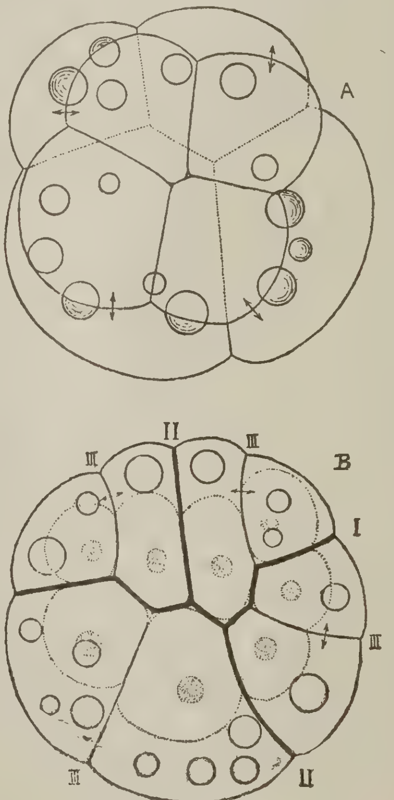

FIG. 2618.—Eight-cell Stage of Nereis. *A*, Normal; *B*, under pressure. Dotted lines show the outlines of the micromeres formed after release from pressure. (After Wilson.)

that the eight-cell stage consisted of a clump of cells separated by two vertical and one horizontal planes. But in spite of this abnormal cleavage a normal embryo was produced.

The results of the *isolation* of blastomeres are complicated. On the one hand we have experiments like Crampton's, where an isolated blastomere of the two-cell stage continues to develop into a half embryo, as if the other half were present; while, on the other hand, we have the experiments of Zoja, who found that isolated blastomeres of the medusæ, Clytia and Laodice, in the sixteen-cell stage would develop into free swimming larvæ which could not be distinguished, except for their small size, from larvæ developed from whole eggs. (Apparently, however, a one-fourth egg of Clytia was the smallest that would develop into a complete medusa.) Between these two extremes there are species presenting intermediate grades in their capacity to develop from isolated blastomeres. So far as we know now, the form that comes nearest to the medusæ described by Zoja in power to develop from isolated blastomeres is Amphioxus. Wilson discovered that blastomeres of the two-cell stage isolated by shaking would develop precisely like whole eggs, giving rise to perfect blastulas, perfect gastrulas, and nearly perfect larvæ one-half the normal size. The same result was obtained from groups of two blastomeres of the four-cell stage. Single blastomeres of this stage, however, might give rise to perfect blastulas and gastrulas, but the larvæ were less perfect. While from the eight-cell stage single blastomeres would produce only imperfect blastulas, most of them developing as if still part of a whole embryo. Morgan found that if one blastomere of the two-cell stage of Fundulus were killed, the other would develop into a perfect embryo two-thirds of the normal size.

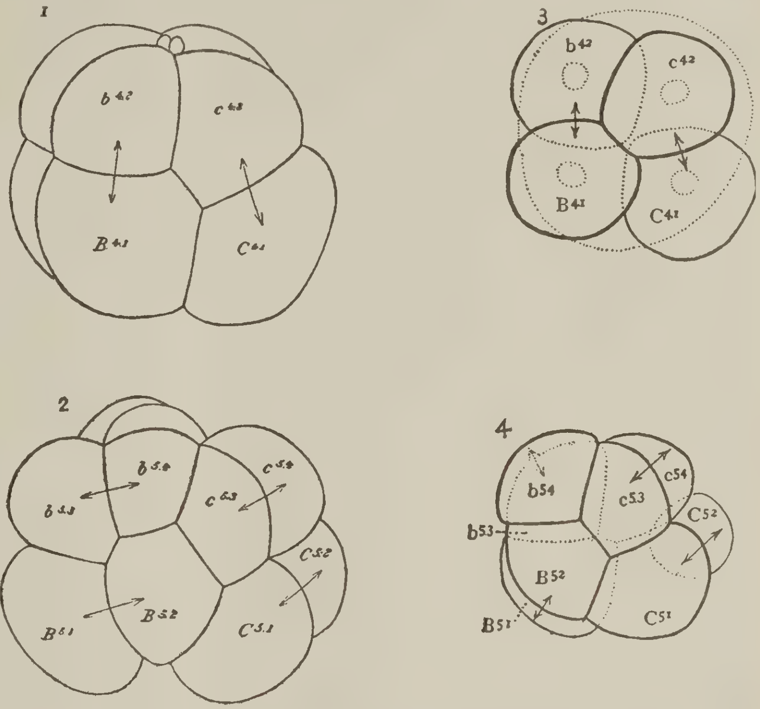

FIG. 2619.—Early Stages in the Development of an Ascidian. 1, Normal eight-cell stage, viewed from the left side; 2, same, sixteen-cell stage; 3, half eight-cell stage developed from an isolated left blastomere of the two-cell stage; 4, same in the half sixteen-cell stage. Note the relative positions of corresponding cells, $B^{4\cdot1}$, $B^{5\cdot2}$, etc., in normal and half embryos. × 250 to 280. (In part after Castle, from Crampton.)

An isolated blastomere of the sea-urchin, Echinus, according to Driesch, develops at first as if it were a half of a whole embryo producing a half blastula. Then the opening closes forming a complete blastula which develops into a gastrula and pluteus. Crampton obtained similar results with eggs of an Ascidian (Fig. 2619).

In the ctenophore, Beroe, we have, as Driesch and Morgan have shown, a condition similar to that found in the gasteropod. Isolated blastomeres of the two- or of the four-cell stage segment as if forming a half or a quarter of a whole embryo, and they give rise finally to imperfect larvæ. Driesch and Morgan made also the interesting discovery that if a fertilized ctenophore egg have part of the cytoplasm removed, it also gives rise to an imperfect larva "showing certain defects which represent the parts removed." This last observation shows that the cytoplasm may be of importance in directing development. For here a defect in the cytoplasm gives rise to a definite deformity in the larva.

All of these results, taken together, make a very strong case against the theory of qualitative divisions. The isolation experiments show that in many cases a nucleus which normally should give rise to nuclei of only one-sixteenth, one-eighth, one-fourth, or one-half the embryo may when isolated produce all of the nuclei of a normal larva. The pressure experiments show, moreover, that even in cases in which isolated blastomeres will not produce whole larvæ, these same blastomeres, if all together, may be shuffled like a pocket full of marbles and yet produce perfect larvæ. Evidently we must seek some cause other than qualitative divisions to explain differentiation.

According to Weismann's theory of determinants, we must not only have qualitative divisions, but the cells of the body must become diverse by a process of self-differentiation. That is to say, the cause of differentiation lies within the cell itself and not only within the cell but in the idioplasm residing in the nucleus. There is no room left in this process for the effects of external conditions. Hertwig, on the other hand, maintains that external conditions form a very important factor in differentiation. That this must be true is demonstrated by the numerous modifications of form that occur as reactions to external stimuli. (See article *Differentiation.*)

It should be borne in mind in this connection that if the idioplasm resides in the nucleus, as we have reason to believe that it does, then the yolk and other constituents of the cytoplasm in the same cell form part of the external conditions relative to the idioplasm. Since the days of Balfour morphologists have universally accepted the belief that the presence of yolk has a profoundly modifying effect upon the course of cleavage.

Morgan and Driesch have presented experimental evidence that not only is this true, but that later stages may be affected by the presence or absence of portions of the yolk in the egg.

Weismann's theory of determinants breaks down, then, when examined critically in the light of the most recent observations. Let us see now what Hertwig would give us in place of it.

According to Hertwig, the fertilized egg is after all merely a cell, and can have no characteristics other than those that properly belong to cells. The impulse for the first division comes either from the nucleus or the centrosome, but the plane of the division is determined by the shape of the egg, the distribution of the deutoplasm, its relative amount, the plane of union of the pronuclei, and so forth. For example, if the egg is oblong, the plane of cleavage will be at right angles to the long axis. If there is more deutoplasm, yolk granules, in one side of the egg than in the other, the egg will divide unequally, the larger segment including that part of the egg which is richer in deutoplasm. In the next stage internal structure of the blastomeres again may have a controlling effect. Blastomeres may again divide unequally for the same reason as before, and those which are the less cumbered with deutoplasm will divide the more rapidly. Now another factor comes in, for as soon as the organism consists of more than one cell, the interaction of one cell upon another affects the mode of cleavage and the differentiation of the cell. At the same time the cells are being affected by stimuli from without the organism, such as light, heat, gravity, and chemical composition of surrounding media. Although the cytoplasm may divide into parts differing in composition and specific gravity, the division of the idioplasm in the nucleus is always *quantitative* only. The two daughter nuclei are exactly alike. Nevertheless, the nucleus controls the differentiation of the cell, and this is affected by the different idioblasts which become active in different nuclei. Which idioblasts shall become active in any cell is determined by the different positions of the nuclei relative to the whole mass and the consequent difference in the stimuli that they receive. Hertwig quotes with approval the remark made by Driesch that "the differentiation of the cell is a function of its position."

There is no preformation of the embryo in the egg. The mosaic theory of the cleavage is a myth, and it is still more mythical to carry this mosaic idea back to the idioplasm of the egg. Preformation exists only in so far that the structure of the egg as a whole determines the character of the first cleavage. The structure of the whole embryo in the two-cell stage determines what the next step in development shall be. *The new characters that appear in ontogeny are really new formations* and not merely the becoming visible of pre-existing latent possibilities. The form of the embryo is the resultant of two factors, viz., the character of the idioplasm, and the nature of the stimuli to which it is subjected. Of these stimuli, those which arise within the organism are the most important in ontogeny, for they are the ones that are constantly changing as development proceeds. The character of the idioplasm determines primarily what the reaction shall be to any given stimulus, and this reaction in turn determines what the stimulus shall be in the next stage. Development is purely a process of epigenesis, and each stage determines only what the next stage shall be.

Wilson takes a position that is somewhat less advanced than that held by Hertwig. He points out that while it is generally true that the relative position of a blastomere determines what shall develop from it, this relation cannot be a purely geometrical or mechanical one, for in different species of eggs blastomeres may exactly correspond in origin and relative position, yet have entirely different morphological value. This is strikingly shown by a comparison of the polyclade egg with that of the annelid or gasteropod. Cells with exactly similar geometrical relations give rise to entirely different organs in the two groups.

Wilson agrees with Hertwig that the differentiation of the cytoplasm in one stage has a determining influence upon the next stage, and he explains the difference between eggs of the gasteropod and the medusa in the ability of single blastomeres to produce a whole embryo by supposing this differentiation to have begun in the former early in the history of the ovarian egg. He does not agree with Hertwig in supposing the somatic nuclei to retain their embryonic character. He points out that the facts of regeneration indicate that the nucleus has undergone a change, and he suggests that the change may be due to a process like that observed in the somatic cells of the segmenting egg of Ascaris. That is, the somatic nuclei do really differ from germ nuclei, but this is because they have given up part of their substance to the cytoplasm, and not, as Weismann would suppose, because they have undergone qualitative division.

Conclusions.—We have now completed a review of the principal fundamental conceptions to be found in theories of heredity. We have seen that the animistic theories belong to the age of mysticism, and receive no confirmation from scientific investigations. We have seen that there is reason to believe that heredity has its foundation in a physical basis, which is the protoplasm of the cell; and this may perhaps be differentiated into physiological units of some kind. Further there is much evidence from observation and experiment to show that the physical basis for heredity forms an idioplasm residing in the nucleus of the cell and more especially in those parts of the nucleus which are composed of chromatin. Whether the idioplasm of the germ cell is essentially different from that of somatic cells is doubtful. The view that such a differentiation does exist is strongly supported on morphological evidence in the single case of Ascaris. The physiological evidence is clearly against a qualitative division of the idioplasm. On the other hand, it indicates some sort of progressive differentiation in the idioplasm of somatic cells during development, a differentiation which begins earlier or later in different species. The causes of this differentiation appear to lie partly within the idioplasm itself and partly in the conditions surrounding it. Both experiment and common sense favor the view that the cell can contain no elements presenting other than purely cellular characteristics. Development is essentially a process of epigenesis. There are as many species of germ cells as there are species of organisms, and the germ cells of any single individual have probably the same degree of variability that other serially homologous organs of that individual have. The normal offspring is similar to its normal parent, because the germinal idioplasm of the two are of common origin, and both have developed under normal conditions. There is no evidence that the germ cells in an adult organism may be affected in any direct way by any changes that may take place in the cells of the body. Therefore the inheritance of acquired modifications of somatic cells is theoretically improbable. *Robert Payne Bigelow.*

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HEREDITY IN RELATION TO THE DEVELOPMENT OF MORBID STATES.—It is almost of the nature of a truism to state that morbid conditions are and can only be either inherited or acquired; yet we are apt to confuse these two modes of production; hence in dealing with heredity as a factor in the development of states of disease it is essential at the outset to lay down clearly what is and what is not inherited. A little consideration shows us that only that is inherited which is the property of the individual at the beginning of the existence of that individual, for once existence has begun any disturbances set up by influences from without—by injury, infection, or intoxication—are obviously acquired. Now individual existence certainly does not begin at the moment of birth; it begins at the moment that the nuclear material of the spermatozoon fuses with the nuclear material of the ovum to form the fertilized cell. Hence that only is inherited which has been conveyed to the individual by the spermatozoon or the ovum, or which directly results from the fusion and interaction of the substances of these two parental cells.

It follows, therefore, that conditions acquired by the individual during intra-uterine existence must be carefully separated from inherited states.* Thus we have to divide morbid conditions into:

A. *Inherited.*
  (1) From the father.
  (2) From the mother.
  (3) Resulting from the interaction of the paternal and maternal germ plasms.
B. *Acquired.*
  (1) Of antenatal acquirement.
  (2) Acquired during parturition.
  (3) Of postnatal acquirement.

In our determination of what is truly inherited we have to recognize that infection as such cannot be inherited; syphilis and tuberculosis, for example, cannot be spoken of as inherited conditions. Not that these infections of the parent may not tell upon one or other of the conjugating germ cells and so lead to disturbed states of ovum or spermatozoon which may materially influence the resulting individual; such indirect influences may, as I shall point out later, lead to the manifestation of *parasyphilitic* and *paratuberculous* lesions; but the actual infection cannot be inherited. There is no such thing as inherited syphilis in the proper sense.

For such infection presupposes the passage of microbes from one or other parent to the offspring through the instrumentality of the germ cells. Apart from the fact that such microbes cannot strictly be regarded as properties of the parental organism, and apart from the fact that the spermatozoon, the germ cell through which this transmission is supposed often to occur, is so small and of such a structure that it cannot be conceived as a carrier of microbes save by adhesion to its exterior, were a microbe or microbes to gain entrance by any means into the ovum, that would be at the most a fortuitous inclusion, and we are not justified in imagining that it could be present without so seriously injuring the cell as to render it barren or monstrous. As a matter of fact the laborious observations of Gärtner upon the number of tubercle bacilli present in the semen of tuberculous guinea-pigs have demonstrated that the probability of a bacillus-bearing spermatozoon fertilizing an ovum is so extraordinarily minute that it may be neglected, while the statistics of Chiari upon the specific lesions of infants suffering from antenatal syphilis show that the liver is the organ most extensively involved in nearly all cases—a sure indication that the channel of infection has been from the placenta; for the blood coming from the placenta first passes through this organ, which thus bears the brunt of the infection.

The not infrequent cases in which a syphilized father begets syphilized children without the mother showing signs of general syphilis, must therefore be due to intra-uterine infection, either by passage of the specific virus from the uterine cavity through the cells of the amniotic sac (this has recently been shown possible in connection with other pathogenetic microbes), or by local infection of the fœtal placenta from the uterine cavity, or by *local* infection of the uterine mucosa and maternal placenta without extension of the disease in the mother, although with conferment of relative immunity upon the mother.

Having now cleared the ground it is possible to discuss the effects of heredity pure and simple. The inheritance of morbid conditions may be: 1. Specific or ex specie, *i.e.*, peculiar to all the members of a species. 2. Racial. 3. Familial. 4. Individual.

1. Ex Specie.—This shows itself mainly in predispositions to certain infections including the disturbances set up by the grosser parasites. The infectious diseases of cold-blooded animals, for example, are quite different from those of warm-blooded, and, while some diseases occur inc ommon, the diseases to which man is liable are, as a series, well differentiated from those affecting cattle. Certain infections like syphilis, gonorrhœa, and typhoid would appear to affect man alone under natural conditions.

An interesting line of thought has been touched upon by Bland Sutton in his "Introduction to General Pathology," where he points out that certain structural features so characteristic as to be differential in certain species and races, are essentially inherited morbid conditions or malformations. He notes that the race of tailless trout of Islay (and we may add the race of Manx cats), the albinic or non-pigmented species of snails; the Chætodon with its remarkable osteomatoid enlargements of the bones, the race of horned men of Akim in Africa with their huge symmetrical exostoses of the malar bones, are all examples of such morbid inheritance. He is inclined to believe that horn and horny outgrowths in general have originated as pathological states, and what is more he would regard the descent of the testicle into the scrotum in man, and other animals which assume the more or less erect position, as an inherited anomaly. Another good example of inherited pathological structures is the pair of "castors" situated on the inner side of either foreleg of the horse. These familiar objects are of cuticular origin, are horny and unconnected with bone; they are constant and apparently useless. The only satisfactory explanation he can suggest for the inheritance of these anomalies is that some prepotent ancestor of the horse conveyed this to its descendants along with other more valuable properties; in other words, that there is a certain correlation in the inheritance of variations.

2. Racial.—Among the members of one species those of a different race show peculiar susceptibilities. Thus among the lower animals, the "Buffel" or native cattle of Austria-Hungary have been found largely insusceptible to tuberculosis, in this differing widely from ordinary domestic cattle; the race of Algerian sheep is refractory to anthrax when ordinary domestic European breeds are peculiarly susceptible. Numerous similar examples can be cited among the races of mankind; negroes are peculiarly liable to succumb to tuberculosis, they suffer from sleeping-sickness, ainhum, etc., and on the other hand appear not to be so susceptible to malaria as are white races. Malaysians show a marked tendency to contract beri-beri, they and the Hindoos (though to a somewhat less extent) and Eastern peoples in general are more liable to contract and to die from the plague than are those of European descent, although the latter show themselves more susceptible to yellow fever. In Canada, as in France, the greater severity of scarlet fever when it attacks those of Anglo-Saxon descent as compared with those of French origin is distinctly noticeable. I have already in the previous paragraph cited some examples of the racial inheritance of anomalies.

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* Chantemesse and Podwyssotsky suggest for the former the term "Uterine Inheritance." I strongly object to this on the ground that in discussing inheritance, we who deal with one branch of biology must conform to the usage of those working in other branches. Intra-uterine existence is characteristic of only one division of animals and that a somewhat limited one. To speak of intra-uterine acquirement as inheritance is a sure means of continuing the present confusion which exists among medical men in connection with this subject.

3. FAMILIAL.—Very numerous examples may be cited of familial inheritance. These examples range themselves in various groups:

(I.) *Inheritance of Anomalies.* Numerous well-recorded examples of cases of polydactyly, syndactyly, abnormal shortness of the phalanges, hypospadias, phimosis, are noted as occurring through several generations.

(II.) Other conditions which may be regarded as *probably anomalies of defect,* and which are markedly inherited, are hæmophilia, albinism, Daltonism, myopia, strabismus, ichthyosis.

(III.) *Diathetic.* The last example together with the tendency to the formation of cataract may possibly come under the heading of diathesis, or liabilities to abnormal functional disturbances occurring at certain periods of life. Among these also are to be included obesity, gout, chronic rheumatism, and diabetes.

(IV.) *Infectious.* It is a matter of popular knowledge that certain families are much more susceptible than is the race in general to acquired conditions like tuberculosis or one or other zymotic disease.

(V.) *Nervous.* The familial nervous conditions are especially worthy of note, because in a remarkable proportion of cases of mental and other nervous disturbances we find a history of antecedent nervous conditions, either homœomorphic, *i.e.*, of the same order, or heteromorphic, of different type. Among the former we recognize inherited paralytic and ataxic conditions, pseudo-hypertrophic and amyotrophic paralyses, Friedreich's disease, etc.; among the latter and more frequently we find mental disorders traceable to ancestral disturbance. There is one well-known county family in England in which a state of weak-headedness varying in its manifestations is traced back to the seventeenth century and is popularly attributed to the prominent part played by a celebrated ancestor in connection with the beheading of Charles I.

"The tendency of late years has been to lay increasing emphasis upon the hereditary factor in the production of insanity, but it is doubtful whether even yet the true bearing and significance of this factor has been recognized."

Carlos F. MacDonald lays down that the so-called exciting causes of insanity play a very unimportant part in the etiology of this disease, except in so far as they may operate to bring about a lowered and disturbed state of the brain and those set in motion hitherto latent inherited conditions or tendencies. In support of this he points out that substantially every individual at some time during his life is exposed, in many cases repeatedly, to many of the so-called exciting causes of insanity, both mental and physical; and yet despite this fact we find that sanity is the rule, insanity the exception.

4. INDIVIDUAL INHERITANCE.—Thus far we have had no difficulty in recognizing and to a large extent comprehending the influence of inheritance in passing down from individual to individual of one species, race, or family, certain peculiarities of constitution. We can understand, that is, that just as there are passed down those grosser properties whereby each member of a species resembles all the rest and differs from members of other species, so there are passed down these morbid constitutional states. It is when we come to study the subject of individual inheritance, the inheritance of conditions that is which have first manifested themselves in one or other parent, that from a medical as from a general biological standpoint we find ourselves in difficulties. So that in order to understand what is and what is not capable of inheritance we find it necessary to probe deeply in order to discover if possible some principle or principles which shall make it comprehensible why certain individual characteristics can thus be passed on in later generations, why others cannot. As Virchow has pointed out, every variation from the normal is strictly a pathological state, however slight it may be, and this whether it acts favorably or unfavorably upon the individual. Hence in discussing theories of inheritance which of necessity bear upon this subject of the production and descent of variations we are still strictly within pathological limits.

But in the first place, before considering these theories, it is well to analyze individual variations, for these it will be seen may be of two orders, some being due to the interaction of the conjugating germ plasms and so truly inherited, others being of the nature of acquirements. Among the latter are conditions of excessive development of one or other function or organ, brought about by continued use of the same; the muscular development of the athlete, the specialized development of the musculature of the fingers and of the nerve centres controlling the same in a pianist, and so on. Of the same order are the general results upon the organism of disease affecting the individual, as of infection due to tuberculosis and syphilis and the zymotic diseases, of injuries, *e.g.*, to the brain, and of intoxications, *e.g.*, plumbism and alcoholism.

In addition to these we have to recognize the occasional occurrence of what is known as "spontaneous variations," resulting in the production of sports. The most clearly marked examples of these are to be found among plants; in a bed of tulips, all apparently growing under the same conditions, an occasional flower may be met with possessing four, five, seven, or eight, instead of the usual six petals. Now while one or more of these variations may be ascribed to atavism—to a breaking back to an ancestral state—all cannot be; that is, the tulip must be derived in the distant past from the precursor of the Liliaceæ having either more, or less than six petals; it cannot be derived from both. And as these conditions of excess and defect are of the same order, it is probable that atavism plays little or no part in the development of sports of this nature. Discussing such cases the only conclusion we can reach is that some influence affecting the root bud at its origin, or, it may be, the abnormal interaction of the pollen and ovum, has brought about an abnormal development. Similarly in man and animals in general, the appearance of a sport in one member of a family is rarely if ever to be ascribed to atavism, but to similar influences acting either at the time of fusion of the ovum or spermatozoon, or telling upon the embryo during the very earliest stages of development.

Further than this, admittedly, we cannot advance in the explanation of so-called spontaneous variations. I refer to this matter because it is necessary to point out that both qualitative and quantitative variations like sexdigitism, Albinism, Daltonism, and hæmophilia, may and do constantly present themselves in the individual, and it is not necessary to assume that some ancestor exhibited a like condition; they may arise *de novo.* What is more, it would seem that there is a peculiar liability for these spontaneous variations to show themselves in succeeding generations, and to become familial. The strain of creamy-white horses preserved for more than a century at Hanover originated from a single sport of this order by careful in-and-in-breeding; as again did the Mauchamp strain of merino sheep with their peculiarly silky wool.

THE INHERITANCE OF CONDITIONS ACQUIRED BY THE INDIVIDUAL.

To us as medical men it is of special interest to determine how and to what extent acquired characteristics tend to be propagated; to what extent does disease in the individual tell upon the offspring; is it possible that besides resulting, it may be, in the production of offspring of lowered vitality, the different acquired infections or constitutional states are liable to influence that offspring in a specific manner in one or other direction and so afford examples of an inheritance of acquired characters?

According to Weismann in multicellular individuals characters acquired by the individual cannot be inherited, or at least it has still to be proved that they can. This I might add is a position that is generally taken by biologists of the present day (*vide* article on *Evolution*).

Weismann's Theory.—To understand Weismann's theory it is necessary in the first place to realize the importance of the nucleus in the cellular economy. This is the controlling agent in the cell: remove it and the cell is incapable of regeneration and proliferation (Nussbaum, Verworn). What is more it is the essential agent in fecundation. As is shown by Van Beneden (1875) in animal forms and by Strassburger (1884) in plants, fecundation is essentially the fusion of portions of the nuclear material (chromatin) of the male and female germ cells. At a later date Boveri showed that equal portions of the male and female chromatin unite to give origin to the new individual. Here then in this remarkable nuclear material is the physical basis of heredity. There is no substance in the fertilized cell which is similarly and equally derived from both parental germ cells.

When now the fertilized ovum proceeds to segment and to develop into the embryo and ultimate mature form, the process is seen to be primarily a division and distribution of the chromatin, so that the nucleus dividing before any signs of fission of the cell body show themselves, there are distributed to each daughter cell apparently equal quantities of the chromatin of the parent cell. Hence, as this process of division continues and the whole cell mass of the adult individual—the whole organism—is developed, each cell in that organism contains a portion or derivative of the original chromatin of the fertilized ovum. But a differentiation is to be made out. The majority of these cells form the tissues of the body and as such are found incapable of undergoing fecundation and giving rise to new individuals. These are Weismann's *somatic cells.* Only a certain number present in the reproductive glands maintain this capacity; they are the *germ cells.* And it is these germ cells which convey to the offspring the parental germ plasm; it is through them and through their nuclear chromatin, in which, as above said, the germ plasm would seem necessarily present, that descent occurs, and as in their turn they are the direct descendants of the germ cells which gave rise to the parent individuals and so contain germ plasm directly derived from ancestor after ancestor, so their essential germ plasm is potentially eternal. It has been passed on from generation to generation; the somatic cells of one generation after another have inevitably undergone death and dissolution; they have, after the simile of Lucretius, served but as the runners passing on the torch of life from one to the other.

Thus far we must follow Weismann, and further, with him we must see that the characters of the individual do not directly depend upon the characters of the body, or soma, of the parents. For these characters are transmitted by the germ plasm of the largely undifferentiated ovum or spermatozoon—by germ cells, that is, which are *not* derived from the body cells, and which never have been in other than a latent condition within the parental body. That body has grown and become differentiated and has been acted upon by its environment, but its function throughout has been to form a protecting envelope for the germ cells.

Such being the relationship, it is inconceivable that any character acquired by the parent in the nature of a gross lesion (the loss of an arm, for example), or again in the nature of a special development of one or other faculty (as, for example, the special dexterity of the finger muscle in a pianist) can be transmitted to the offspring. And as a matter of fact we know that the children of those who have lost a limb are born with a full complement of limbs; that ritual circumcision practised for long centuries by Jews and Mohammedans has not resulted in inherited phimosis, and that the docking of tails of horses has had no effect upon the length of tail of their offspring.

These considerations, while they throw light upon the exact nature of descent and while they explain largely the likeness of successive generations in one species or family, do not explain the other important condition of *variation.* For if, as Weismann repeatedly affirms, the environment of the germ cells while in the parental organism has a minimal effect upon them, we do not so far gain any comprehension of how it is that, although derived from intermingling of the same germ plasms, the various offspring of one pair of mankind, fish, or any other animal, while resembling each other in their main features, differ obviously the one from the other, so that no two animals of the same species or even of the same family are absolutely alike. Still less do these considerations explain the occurrence, in certain of the offspring of one pair, of features absent from either parent but present in one or other ancestor (atavism).

To explain this individual variation and kindred matters Weismann has developed a most elaborate theory, so elaborate, and undergoing so many modifications as new facts have presented themselves, that it is impossible to present it in its entirety in the limits of this article. Briefly, he has conceived the germ plasm or nuclear chromatin to be composed of an enormous number of individual particles or *biophores* derived from the ancestral germ plasms on either side. Prior to fertilization a remarkable process of reduction is observable in the nuclei of both the male and female germ cells whereby, according to Weismann, at the time of fertilization each conjugating cell contains only half the number of biophores originally present. By this reduction it comes to pass that through conjugation the fertilized ovum contains the normal number of biophores, half of them derived from the male and half from the female germ cell. Thus in each successive generation the germ cells will contain biophores derived from the male and female germ cells of the previous generation. And, carrying out this conception, it will be seen at the end of say, one hundred generations, the number of representative biophores derived from the whole chain of ancestors (even if as Weismann suggests these are so small as to be quite invisible) would be so enormous, but for this process of reduction with their number being halved prior to each fertilization, that they could not be conceived as capable of being crowded into one nucleus.

Now in this process of reduction Weismann lays down that there is no regular order of discharge of the biophores or ids; they are intimately commingled; representatives or determinants derived from certain near or remote ancestral germ plasms, must drop out; and so it happens that each mature germ cell contains a different series of these. Thus each individual is the outcome of the action of a different series of combinations of these biophores, and as such differs from every other individual.

This theory also demands that if these biophores are the essential and controlling constituents of the nuclear material, then, in division or segmentation of the fertilized ovum, nuclear chromatin and with it germ plasm is transmitted to each cell forming the organism. And to explain the difference in structure and characters of the cells forming the different tissues Weismann is forced to suppose that there is a *qualitative* difference in the transmission to the different cells and that so the different organs and tissues depend for their characters upon different combinations of the biophores, which in the process of successive segmentation of the blastomeres gain entrance into and determine the composition of the nuclei of the different forms of cells. The inheritance of special, racial, and familial features peculiar to and showing themselves in structural and other features of the body is thus, according to him, essentially due to these biophores, their particular distribution and their controlling action.

These, for our present purposes, are the main outlines of Weismann's celebrated theory. Others, among whom may be mentioned Darwin, Roux, de Vries, and we ought specially to mention Francis Galton, had previously enunciated theories or considerations along the lines here indicated, but to Weismann certainly must be given the incredit of elaborating a theory which attempts to cover the whole subject. As this theory has influenced the whole study of the subject of heredity, it has been necessary to explain to this extent its main tenets.

It will be seen from what I have stated that chromatin exists, and in the fertilization of the germ cells undergoes a remarkable series of changes; prior to fertilization there is a remarkable reduction in the nuclear substance. In indirect cell division a somewhat parallel series of changes are to be made out. All these are known facts which can be followed and readily observed; but biophores, ids, and idants have never been recognized; they are creatures of the imagination, and what is more, recent researches have shown that they cannot account for the facts of heredity.

From what I have stated it will be seen that this theory requires for the upbuilding of the organism that a special set of these biophores becomes distributed to each of the early blastomeres, so that eventually sundry of these find their way into the mother cells of each separate tissue. As a general rule in bilaterally symmetrical animals it has been determined that the first segmentation of the ovum leads to the formation of two blastomeres, one on either side of the median plane, which correspond and give rise to the future right and left halves of the body. Thus, according to Weismann, a set of biophores which will lead to the development of the organs of the right side passes into one blastomere, a set for the organs of the left side into the other. But now the observations of Driesch, confirmed and expanded as they have been, more especially by Morgan of Bryn Mawr, by E. B. Wilson of Columbia, by Zoja and others, show that in the two-, four-, eight-, and even sixteen-cell stage of the segmenting ovum of quite a number of animals, the blastomeres can be shaken apart and each separate cell may show itself capable of developing into a complete, if dwarfed larva. Again, as Roux, of Breslau, showed years ago, if a given blastomere of the frog's ovum be destroyed, that is to say one holding a definite position in regard to the rest, the individual is liable to develop minus one special portion of the body—one side of the head for example, one hind limb or quadrant. This, while it would seem at first to point in favor of Weismann's view, is nevertheless no proof that individual blastomeres contain special germ plasms, for as Driesch and others have shown, if the segmented ovum in the morula stage be submitted to pressure and the blastomeres be forced into abnormal relationships, upon removing the pressure the individual blastomeres do not continue to segment and produce those organs and parts which they would have done in normal conditions, but, according to their newly acquired position and relationship toward the rest so do they now proceed to develop; there is, in short, an exchange of properties. So that to a very large extent the prospective development of given cells is, as Driesch has laid down, a function of their relative position. It certainly is not determined by primary qualitative modifications of the nuclear chromatin.

Yet clearly this is not all. Mere relative position of the segmenting cells of the ovum does not determine the eventual structure of the adult. The eggs of a vast number of species are curiously alike, and what is more, under like environment, the earlier segmentations are along the same lines, and yet these eggs give rise to individuals absolutely dissimilar and belonging to wholly different species. There is, I need scarce say, a something in the nature and composition of the ovum—nay more, we can go further and say—of its nuclear constituents, which determines the eventual structure of the individual and this something is conveyed by the parental germ plasm. Thus while denying as wholly inadequate Weismann's theory of "determinants" and also being unable to explain heredity and variation by any conception of fixed morphological gemmules, pangenes, biophores, etc., we nevertheless have to attribute directive properties to the germ plasm and its contained idioplasm. Is it possible to conceive the idioplasm of the fertilized germ cell as being of such a nature that with the progressive growth and segmentation of the embryonic cells, set up by its agency, it undergoes progressive modification according to the forces acting upon it in the different cells of the embryo to which it is distributed? Let me indicate the lines along which we may develop such a theory:

THE CHEMICO-PHYSICAL THEORY OF INHERITANCE.

The primary property of living matter, whereby it is distinguished from non-living matter, is the capacity of growth—is the capacity manifested by that living matter to assimilate non-living matter of certain orders, to absorb it and, in so doing, convert it into matter like unto itself, in doing which work is performed. As I have pointed out elsewhere, looking upon living matter in this light and recognizing that its other properties are but secondary manifestations and outcomes of this capacity for growth, we see that multiplication of the cells composing the individual, and multiplication of the individual (whether by simple fission as in certain unicellular organisms or by the development and emission of germ cells as in multicellular organisms) are in essence means whereby it is insured that the living matter of the individual continues to absorb and assimilate new material, means whereby to insure its continued existence and activity. Reproduction thus, as it occurs in man, is but a form of interrupted growth and a means of carrying on and carrying downward the living human substance.

When we come to inquire what is the nature of growth we see, as above indicated, that it is essentially a process of conversion—a chemical process. Certain substances through the agency of this living matter undergo chemical change and are united with and converted into the living substance. The living cell unit is thus to be regarded as composed of at least two substances—the *idioplasm* or essential and directive living matter, and the *cytoplasm* or, better, *paraplasm* consisting of substances absorbed but not yet converted, of the remains of substances, portions of which have been assimilated, and of various formed elements developed and controlled by the idioplasm. Accepting this as the chemical basis of life and of growth, can we go further and picture to ourselves the manner in which the molecules of living matter undergo the process of accretion and multiplication? The modern working conception of the structure of complex molecules is that these are composed of a central radicle or series of radicles which are united relatively firmly in the form of a ring. This method of attachment does not necessarily result in the attachments of all the combining atoms and radicles being brought into play and "saturated" and the ring thus becoming closed. The atom of carbon, for example, is quadrivalent; capable, that is, of uniting with four atoms of hydrogen. If in such a ring it is united with an atom of hydrogen on either side, this still leaves two attachments free, and to these two surfaces there may be lateral attachments of other atoms or radicles.

Our conception, therefore, of the molecule of idioplasm is that it consists of such a central ring with attached side chains formed of various radicles and combinations of atoms. Judging from the results of analysis of cell substance, the molecules of living matter are extraordinarily complex; the figure here given is, I need scarcely say, but diagrammatic and illustrative of the structure of these molecular rings; in it the composing atoms or radi-

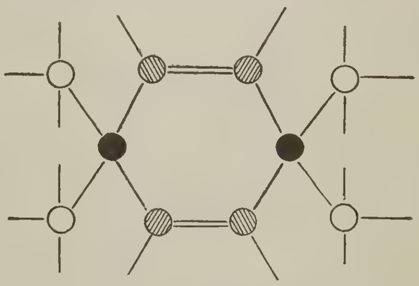

FIG. 2620.

cles are supposed each to be capable of gaining four attachments.

Assimilation then must be regarded as a process in which certain unsaturated surfaces of constituents of the side chains become saturated, and we can conceive growth, that is, multiplication of the molecules of idioplasm, as being brought about by a process of progressive building up of new rings with their attached side chains in intimate connection with pre-existing rings, the new molecule when completed breaking apart (*vide* Fig. 2621).

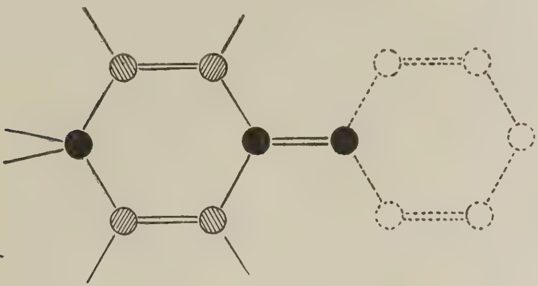

FIG. 2621.

If now we take this as our fundamental conception and postulate further that sundry side chains may be added or removed without destroying the cardinal properties of the molecule, as also that the longer a side chain remains in relation to the central ring (or it may be the more multiple the attachments it gains to that central ring), the more fixed it becomes as an integral portion of the molecular constitution,* we then gain the basis for a physico-chemical theory of inherited variation.

Let us take the simplest example that offers, that, namely, of the bacteria. We know that, preserved in the same environment, these retain the same characteristics for a long series of generations. In other words, the same food-stuff being presented for assimilation, the idioplasm enters into combination with a certain definite number of the constituents of the same; when the increase of this idioplasm has reached a certain point fission or division occurs and the substance of the individual divides into two like parts, each containing idioplasm of the same composition. Hence these two members of the second generation are identical in characters and carry on the particular and distinguishing properties of the species. We know also that, grown on different media the same strain of bacteria exhibits fine points of difference in size, rate of growth, pathogenicity, etc. In other words, a different food-stuff being presented for assimilation the idioplasm combines with somewhat different substances and so forms somewhat different side chains. If this growth on different media is not continued for too long, return to the original medium leads to complete return to the original characters.

But we know also from several examples that growth under widely different conditions for a short period, or subjection to less widely different conditions for a long period, is capable of impressing such alterations upon bacteria that these modifications persist, it may be for years after return to previous environment, *i.e.*, the change in the constitution of the idioplasm has become *relatively* fixed. Thus Roux with the action of minute quantities of carbolic acid added to the medium of growth has developed an asporogenic variety of the anthrax bacillus; by growth at higher temperatures several observers have produced more or less permanent colorless races of pigment-producing bacteria, while Vincent has succeeded in making non-virulent bacteria, like the B. Megatherium, intensely virulent for the animals of the laboratory.

Without discussing at length the modifications introduced by multicellular organization and by descent following upon conjugation of germ cells emanating from different individuals, following these lines of reasoning it will, I think, be evident that we can conceive heredity in higher animals as being brought about by the transmission from generation to generation of idioplasm of a certain chemical composition, which idioplasm, present in one form in the germ cell, becomes inevitably modified in one or other direction as the ovum segments and the cells of different areas of the embryo and developing tissues of the body become subjected to different chemical and physical activities according to their relationship one to the other and to the exterior; so that the eventual structure of the different tissues is the manifestation of the different modifications which this controlling idioplasm has undergone in the course of embryonic and fœtal life. Or, otherwise, a given idioplasm in a given normal environment must follow a particular line of growth and differentiation, so that under like conditions successive generations inevitably resemble each other (*heredity*). With conjugation, however, and the fusion of distinct idioplasms *variation* is induced. The result of the conjugation is an idioplasm having properties not absolutely identical with those of either parental idioplasm. The resulting individual, while resembling, varies from either parent.

We now are in a position to discuss how and to what extent conditions acquired by either parent are capable of being inherited, either directly—the offspring showing the same morbid state as did the parent, or indirectly—disease of the parent having an influence upon the organism of the offspring, but this of a different order from that manifested in the parental organism.

1. *Mutilation.* Gross lesions of the body tissues can at most, according to this theory, only affect the offspring indirectly. They cannot be directly reproduced in the offspring; only in certain cases, by bringing about a poorer state of nutrition of the parental organism in general, and so of the germ cells, may they lead from the offspring not attaining full development.

The only well-authenticated example frequently quoted as an instance of the inheritance of gross lesions—viz., Brown-Séquard's experiments in which by sections of nerves, etc., in guinea-pigs, he produced epilepsy which manifested itself in the offspring—is not, it may be noted, an example of the inheritance of gross lesions, but is an example of the inheritance of a constitutional state set up in the parents by such a lesion. What is more, repeated attempts to confirm these experiments have failed. We do not doubt that Brown-Séquard obtained the results recorded by him, but under the circumstances the only valid explanation is, that he experimented with animals of lowered vitality, this showing itself especially in the direction of nervous instability, and that the nutritional changes following upon his operations led to the offspring being of still poorer constitution and still more unstable. (*Vide* paragraph 3 A, following.)

2. *Acquired Overdevelopment and Relative Excessive Function in One or Other Direction.* Similar considerations show that these cannot be directly transmitted to the offspring. At most, full and harmonious exercise of sundry functions of the body by leading to increased nutrition may tend toward a healthy sound state of the system, and by insuring general good nutrition may insure good nutrition and assimilation on the part of the germ cells, and so tend toward a sound condition and good development of the offspring.

3. *Intoxications (Including Infections); Indirect Effects.* Inasmuch as we cannot regard the germ cells as lying absolutely inactive and inert within the parental reproductive organs, and must from every consideration regard them as undergoing metabolism—assimilating food-stuffs from the surrounding lymph and discharging the products of their metabolism, so does it follow that the diffusible toxic substances capable of acting upon the cells of the body generally, when circulating through the tissues, must be liable to be absorbed by the germ cells and

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* I have discussed the grounds upon which we may make these assumptions in the article already referred to.

so *may* alter the constitution of their idioplasm.* Nor do we lack clear evidence that this actually occurs. Thus Mairet and Combemale have subjected male dogs to chronic or acute alcoholic intoxication and found that the young exhibited various arrests of development and were predisposed to epileptoid seizures. The only explanation is that the alcohol had caused deterioration of the spermatozoa so that these conjugating with a healthy ovum nevertheless gave origin to impaired individuals. Nor are clear cases wanting of similar degenerations occurring in the progeny of alcoholic fathers and healthy mothers in man. The most clear example, however, of this order was afforded years ago by Constantin Paul in connection with the effects of lead poisoning. Studying a series of cases in which the father alone in the course of his work became the subject of plumbism, he was able to obtain the history of 32 pregnancies. Of these 12 resulted in the death of the fœtus before term; 20 children were born alive, of which 8 died during the first year, 4 died during the second year, 5 died during the third year, and 1 died later. Two alone were found to be alive, one of these aged twenty.

The only conclusion from these observations is that substances which lead to intoxication in the parental system tend also to act deleteriously upon the germ cells. It will be seen that the individual offspring itself is in one respect the direct victim of the intoxication; inherited plumbism is lead poisoning acting initially upon one or both of the conjugating germ cells, but it must be clearly understood that the mental and other disturbances showing themselves after birth are not the results of the action of lead salts still circulating in the system and that thus the lesions of inherited plumbism are of a totally different order from those of acquired plumbism. These are one and all lesions of incomplete development.

3 A. *Neuropathies.* The effects of parental intoxications are peculiarly liable to show themselves in the form of conditions of imperfect organization of the nervous system. This is in accordance with the principle or law, the action of which we repeatedly see in evidence: the law, namely, that characters which are the last to be acquired by the individual, the race, or the species are those which are the first to be lost. Thus in the evolution of man, one of the last acquirements—that acquirement whereby man is distinguished from all other animals—has been that of the higher mental organization. Another has been the development of relative insusceptibility to sundry infectious diseases. Thus the individual whose full development is arrested is particularly liable to manifest a greater or less degree of mental instability, the development of the higher nervous centres being incomplete; or again to manifest a peculiar susceptibility to the infections liable to attack human beings. Thus nervous instability of various orders may be regarded as an evidence of familial degeneration and as due to a condition acquired by one or other parent or to inheritance from previous ancestors, and noticeably may be accompanied by other stigmata of incomplete development and degeneration, liability to contract infectious disease, etc.

3 B. *Increased Susceptibility toward Infectious Diseases.* What I have stated regarding neuropathies may be stated *mutatis mutandis* with regard to infections. That is, the toxins of one or other infection circulating through the system, becoming absorbed by the germ cells and acting chemically upon the idioplasm, may result in the weakening of that idioplasm. As a matter of fact Gheorghiu has pointed out the frequency with which one notes the history of parental infection in cases of various monstrous developments.

It may be and it has been urged that here we are not dealing with the inheritance of conditions acquired by the parent, that the toxic substances produced these results not by their action on the body cells, but by direct action on the germ cells, and that so the inheritance is blastogenic, not somatogenic. We are quite prepared to grant that these inheritances are of blastogenic origin, nevertheless they are of individual acquirement. The individual consists of body plasm and germ plasm, and whether the defect tell primarily or secondarily upon the germ plasm of the individual we here have examples of conditions acquired by the individual transmitted to the offspring. We have to admit, that is, that the environment of the germ cells when present in the parental organism is capable of bringing about modifications in the germinal idioplasm, and so of producing variations in succeeding generations.

4. *Intoxications, Infections, and Diatheses; Direct Inheritance.* From the above considerations it will be seen that we have reduced the possibilities of the direct inheritance of acquired conditions to a relatively narrow field. We have not, however, completely removed all of them; certain conditions remain to be discussed. Is it possible, for example, that these various parental intoxications, telling as they do in one or other direction upon the parental constitution, tell also in a differential manner upon the germ cells, so that alcoholic inheritance differs from inherited plumbism, and these again from the indirect inheritances of syphilis and tuberculosis? *A priori* if these toxic substances, circulating in the parental system and gaining entrance into the germ cells, forming different combinations with the idioplasmic molecules, combine with, that is, or alter different side chains, we must conclude that it is possible. As a matter of fact, children of syphilitic parentage not the victims of intra-uterine syphilis, tend to show parasyphilitic lesions which are of a somewhat different order from the paratuberculous lesions of the progeny of tuberculous parentage. Here, however, it has to be admitted that fuller statistics are necessary regarding the lesions of those whose fathers and mothers respectively have suffered intoxication; for in maternal intoxication of any order, placental absorption of the circulating toxic substance must tell upon the fœtal existence. Nevertheless, taking the germ cells as, from their potentialities, apparently representative of the body cells in general, the abundant studies upon immunity made during recent years give us the strongest grounds for believing that the different toxins act specifically and affect the idioplasm in one particular direction. At this point it will be seen that our theory falls into line with Ehrlich's side-chain theory of immunity.

In short, the facts gained from the study of immunity point to three possibilities:

(*a*) Where through disease or through introduction of toxins the cells of the body become inmunized to one special infection, those cells are so modified that they now produce substances antagonizing the toxins of that infection. We might therefore expect specific parental immunity to be accompanied by specific immunity of the germ cells and a condition of relative immunity of the offspring.

(*b*) When through disease immunity is not attained, but on the contrary the parental tissues—as in progressive tuberculosis—become progressively weakened and susceptible to the deleterious action of the toxin, the germinal idioplasm may also be weakened and an offspring be developed more susceptible to the particular infection.

(*c*) The idioplasm of the germ cells, being relatively undifferentiated while within the reproductive glands, might not in this state possess side chains capable of being acted upon by the circulating toxins; so that while the parental organism in general is affected thereby in one or other direction, the germ cells may be uninfluenced, and the offspring in consequence may present neither increased susceptibility nor increased powers of resistance to the specific disease.

Here it will be seen that we are in a region of hypothesis pure and simple; indeed, our researches into the inheritance of specific morbid constitutional states have not been sufficient to indicate positively which, if any, of these possibilities accords with the ascertained facts. Even granting that the first of these possibilities is correct, it has to be noted that according to the principle already mentioned—that conditions last acquired are those soonest lost,—we should expect that acquired immunity of the germ cells, if obtained, would tend to be of slight duration, not strongly impressed. Hence for the development of acquired immunity as of acquired susceptibility, not a single act of immunization of the parent but repeated immunizations through several generations might be requisite before any marked and permanent influence showed itself. As a matter of fact, the various attempts to confer immunity by immunizing the male parent have in the main given negative results. Gley and Charrin alone have detected such; Ehrlich strenuously denies that it is obtainable.

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* I say *may* because it has to be remembered, as pointed out by Meyer, that the cellular absorption of toxic substances is of two orders: (I.), absorption into the cell without resulting chemical combination (as in the case of the alkaloids), the absorbed substance interfering with metabolic processes, and (II.) absorption with chemical combination, the toxic substance becoming fixed, *e. g.*, tetanus toxin in the cells of nerve tissue.

Nevertheless I think it is useful to call attention to these possibilities in order that more exact studies be made which shall prove or disprove them. Thus far the importance of determining the part played by acquired disease, more especially in the father, in the development of morbid constitutional states of the offspring has not been sufficiently recognized. It has not been grasped by our profession that in the study of these states we have a more subtle means of determining this question of the inheritance of acquired states than can possibly present itself to the morphologists, dependent as they are upon the more extensive gross anatomical changes before they can determine whether any alteration has been impressed upon the offspring.

We have, as I have pointed out, definite evidence that constitutional disturbance in the parent affects the germ plasm, and having this, it is for us sedulously to collect all the evidence which presents itself in order that we may determine the limitations of this affection of the germinal idioplasm within the parental organism.*

The views here enunciated are, I know, contrary to the generally expressed opinions of morphologists. It is well to point out once again that the conception of the existence of micelli, ids, gemmules, etc., can only lead to the view that acquired characters, not being able to tell on these ancestral bodies, cannot possibly be inherited. Save in the matter of spontaneous variation I do not suggest that visible anatomical changes can be expected in the course of one generation; but this physico-chemical theory, by realizing the possibility of progressive modification in the constitution of the idioplasm while within the parental organism, is fitted to explain not only what we observe in connection with the effects of disease, but also the development of familial and racial characters, and to aid materially our comprehension of the nature of evolution in general. *J. George Adami.*

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HERMOPHENOL, mercury phenol-disulphonate of sodium, is a white, amorphous powder soluble in five to seven parts of water. It is said to contain forty per cent. of mercury, and to be strongly bactericidal without caustic effect on the tissues. It can stand a heat of 120° C. without decomposition. Bérard uses it as a disinfectant for the hands, and in three-per-cent. solution for ophthalmia neonatorum, and Reynes injects 4 c.c. (ʒ i.) of a half-per-cent. solution, every two or three days, for syphilis.

W. A. Bastedo.

HERNIA.—This term, derived from the Greek *ἕρνος* (a spout), is employed for denoting the protrusion of a viscus from the cavity in which it is normally contained. Although it may be used to denote the escape of organs from other cavities, yet when unqualified it signifies, as does the vulgar term "rupture," a protrusion from the abdominal cavity. As usually employed it implies a pouching of the containing wall forming a continuous sac for the displaced contents. An escape of the viscera through a wound in the wall is better termed a "protrusion." The term "internal hernia" is employed to denote either the protrusion of the abdominal contents into the thoracic cavity—*i.e.*, *diaphragmatic hernia*—or the introsusception of the intestine into one of the peritoneal fossæ. The latter condition is, however, more properly classified as one of the forms of intestinal obstruction.

A hernia may occur at one of the openings of the abdominal wall normally present in fœtal life, which has not become closed at the time of birth, and is then termed a *congenital* hernia; *i.e.*, a congenital inguinal hernia is one in which the abdominal contents push their way into the unobliterated processus vaginalis. All herniæ developed subsequently to birth are termed *acquired.* They occur at the points where the abdominal wall is relatively weak. Hence arises the anatomical classification of herniæ: inguinal, femoral, umbilical, lumbar, diaphragmatic, obturator, etc. The parts constituting a hernia are, first, the sac and, second, the contents. The sac consists of peritoneum continuous with the parietal peritoneum of the abdominal cavity. The coverings of the sac vary with the anatomical variety of the hernia, and are as a rule fascial with the exception of the skin. The shape of the sac depends upon the nature of the opening in the abdominal wall and the degree of restraint afforded by the fascial coverings. If the opening be circular with more or less sharp margins the sac as a rule is globular, as in umbilical and femoral herniæ.

In inguinal hernia the sac is elongated, owing to the fact that the fascial coverings are tubular. If the hernia is incomplete the sac is sausage-shaped. On the other hand, it is pyriform in shape when the hernia becomes scrotal. Bands of the investing fasciæ may constrict the sac in such a manner as to produce hour-glass forms; or from the same cause diverticula may result, the pressure being unequally exerted. The parts of a sac are termed the mouth, the neck, and the fundus or body. The contents of the sac usually consist of small intestine or omentum, or both; more rarely they consist of the colon, cæcum, or appendix, sigmoid flexure, bladder, or uterine adnexa. When the contents consist of intestine alone the hernia is called an enterocele; when of omentum alone an epiplocele; when of both, an entero-epiplocele. Fluid may be found in the sac either free or encysted by adhesions—*hydrocele of the hernial sac.*

ETIOLOGY.—Causes predisposing to hernia are:

1st. *Heredity.*—Weaknesses in the abdominal wall predisposing to hernia are undoubtedly inherited.

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* More especially I would call attention to the valuable material in the possession of the great American insurance companies and the possibility of gaining information as to the effects of acquired disease of the parent upon the offspring by employing the mathematical methods elaborated by Carl Pearson (*vide* article on *Evolution*); if they can give mathematical expression to the influence of, say, acquired parental tuberculosis, upon the life period of the offspring, we shall make a most material advance.

Macready[1] estimates that twenty-five per cent. of patients with hernia give an ancestral history.

2d. *Sex.*—About six males suffer from hernia to one female. This is to be explained both by the much greater frequency of inguinal hernia in males, due to the necessary enlargement of the inguinal canal, and by the nature of their occupation.

3d. *Age.*—Except in the period of infancy, when the influence of congenital weakness upon the development of hernia is most marked, the greater number of herniæ occur in the active period of life, between fifteen and fifty.

4th. *Elongation of the Mesentery*, although generally given as an etiological factor in the production of hernia, is rather a concomitant result—with hernia—of causes such as weakness and laxity of the abdominal wall.

Exciting Causes of Hernia are: 1st. Occupations necessitating violent muscular efforts. 2d. Strains, as lifting, coughing, sneezing, and parturition. 3d. Conditions producing stretching of the abdominal wall, as pregnancy, ascites, obesity. 4th. Atrophic changes, as senility. 5th. Traumatism resulting in the replacement of normal by cicatricial tissue, or in the destruction of nerves, thus causing paralysis and atrophy of muscle.

Clinical Varieties of Hernia.

The clinical classification of herniæ is based upon the condition of the contents and the relation of the contents to the sac. Thus we have: (*a*) Reducible; (*b*) irreducible; (*c*) inflamed; (*d*) obstructed; and (*e*) strangulated herniæ.

(*a*) Reducible Hernia.—A reducible hernia is one in which the entire contents can be wholly reduced to the abdominal cavity, without recourse to a cutting operation. Reduction is often effected by posture, but may be accomplished only by taxis. It is the most common class of hernia.

Symptoms.—The earliest subjective symptom in an acquired hernia is usually pain (ninety per cent. of cases).

In a hernia caused by a strain the pain may be sharp and accompanied by a sense of something giving way. Usually it is dull and dragging and, after a varying period of time, is replaced by a sense of fulness which is marked on standing or straining and disappears in the reclining position. Large herniæ are not infrequently accompanied by gastric or intestinal symptoms, which are probably reflex in character.

The objective symptoms depend upon the size of the hernia and the nature of its contents. A small hernia exhibits a tumor as a rule only on standing or coughing, and the latter disappears when the patient lies down. A large hernia is often not spontaneously reducible; but it increases in size in the erect position or on coughing, and if inguinal it may then be seen to descend into the scrotum or labium.

In both small and large herniæ a characteristic impulse is felt on coughing. In an enterocele there may be a gurgling felt or heard either at the moment when the bowel descends into the sac or on reduction of the hernia, and at the same time the tumor is more or less tympanitic. An epiplocele is dull or flat and feels more irregular and does not give so marked an impulse.

Diagnosis.—See Anatomical Varieties.

Treatment.—For taxis, see Strangulated Hernia. For operative and mechanical measures, see under Anatomical Varieties; also under Mechanical Treatment.

(*b*) Irreducible Hernia.—This term is applied to a hernia in which the contents, although practically normal in condition, cannot be wholly returned to the abdominal cavity. The chief causes of irreducibility are, first, adhesions of omentum to the sac or between the contents, or thickening of the imprisoned omentum (according to Macready the contents consist of omentum in ninety per cent. of cases); secondly, the formation of part of the sac by the gut itself (more fully described under cæcal and sigmoid herniæ); and, thirdly, the bulk of the hernia may be so great that the contents cannot be received into the abdominal cavity.

Irreducible hernia is more frequently observed in middle life and in the umbilical variety. It is uncommon in children. It may be permanent or transitory. It is said that it seldom persists throughout life.

Symptoms.—The symptoms depend upon whether the hernia is large or small and upon the nature of the contents. Small epiploceles usually give no especial symptoms, while larger ones, from dragging upon the omentum, are liable to cause digestive disturbances and are prone to inflammation. In irreducible enterocele the condition is more serious. The imprisoned bowel is apt to become obstructed, which condition may be evanescent or may persist, and furthermore strangulation may supervene. Hence the symptoms vary from occasional attacks of colicky pain and flatulence, with more or less constipation, to those of complete obstruction and strangulation.

Treatment.—Herniæ which have only recently become irreducible are, as a rule, more or less inflamed or at least congested; so that rest in bed and the application of cold with moderate pressure are indicated. Prolonged efforts at reduction under such circumstances are more than likely to aggravate the condition, and hence considerable judgment has to be exercised in the employment of taxis. In old cases or those in which the above treatment does not suffice, operation is indicated. The contraindications to operation do not exist to the same extent as in reducible hernia, since the condition *per se* is more dangerous. In cases in which operation is distinctly contraindicated, as in the aged or diseased, or in which the hernia is so large that the return of the contents to the abdomen would not be feasible, the employment of some device for supporting the hernia and preventing its increase is indicated.

For umbilical hernia some form of abdominal support is useful. In large scrotal herniæ a stout canvas bag, supported from the shoulders, has been found advantageous.

The employment of special trusses, as the "hinged-cup truss" for inguinal hernia, can be recommended only when operation is out of the question, although Macready claims sixty-eight per cent. of reductions by its use. But even then a cure of the hernia is seldom attained.

(*c*) Inflamed Hernia.—When a local peritonitis occurs in the hernial sac the hernia is said to be inflamed. It is usually the result of trauma, either from a truss or from prolonged taxis, but it also occurs from disturbance of the contents as from obstruction or possibly enteritis. A strangulated hernia always becomes inflamed if the condition persists for any length of time. Irreducible herniæ are most prone to inflammation, especially the femoral and umbilical varieties. The process results in the production of lymph and fresh adhesions. The sac may become distended with fluid, and obstruction and strangulation may supervene.

Symptoms.—A sense of increased fulness, pain, and tenderness are present. There is usually a slight rise of temperature. There may be vomiting and constipation. If obstruction or strangulation occurs the symptoms of this condition supervene. On palpation there are tenderness and local heat, and the mass may be tense or semifluctuating. Inflamed omentum usually feels hard and nodular.

Treatment.—Rest in the recumbent position and the application of heat or cold. Enemata, but not cathartics, should be used. The pain may be relieved by anodynes.

(*d*) Obstructed Hernia.—An obstructed or incarcerated hernia is one in which the passage of the contents of the intestine is inhibited, but in which the circulation of blood is not interfered with.

Obstruction is more common in irreducible than in reducible herniæ. As it is usually due to constipation, it occurs more often in herniæ containing the large intestine. Hence we find it more often in umbilical herniæ and in large inguinal herniæ in which the contents are the sigmoid flexure or cæcum. As large herniæ are more common and as there is a lack of intestinal tone in the elderly, obstruction occurs most frequently during the period from middle life on.

The determining causes are usually neglected constipation, and the ingestion of indigestible food or food that leaves a large residue.

Symptoms.—The symptoms vary considerably, but are distinguished from those of strangulation by their gradual development. Constipation at first is not generally absolute. The tongue is coated, the breath is foul, and there is complete anorexia followed by vomiting, which is not usually persistent and seldom stercoraceous. There is colicky pain which may be severe, but there is no collapse. Distention is more or less marked. The hernia, if before reducible, becomes irreducible and increases in size. Impulse, however, is obtainable, which serves to eliminate strangulation. The tumor is often doughy and may be dull on percussion, although imprisoned gas may give a tympanitic note. The prognosis is usually good.

Treatment.—The emptying of the bowel is the first consideration, and this should be accomplished by high enemata and by massage of the hernia. Cathartics should not be given until the tumor has decreased in size.

If there be no response to treatment, and if strangulation be suspected, operative interference should be at once instituted, as delay may be fatal. Recurrence of obstruction may be to a large degree averted by proper attention to the food and bowels.

(*e*) STRANGULATED HERNIA.—A strangulated hernia is one containing intestine in which both the passage of bowel contents and the circulation of blood are interfered with. For the time being it is not spontaneously reducible.

This condition is rare in infancy and is most common in middle life and old age. It occurs more often in small than in large, and in old than in recent herniæ; although rarely a hernia may become strangulated on its first appearance. Narrowness of the neck of the sac conduces to it. Hence it is more common in femoral than in other varieties, and in irreducible herniæ when the neck is partially occluded by adherent omentum, as in some umbilical herniæ. According to Berger, the risk of an inguinal hernia undergoing accident is 2.16 per cent., of a femoral 9.02 per cent.

Determining Causes.—Among the more common causes may be mentioned straining, such as occurs in lifting, sneezing, coughing, etc., in all of which acts there is an increase in the intra-abdominal pressure. Consequently all conditions predisposing to such strain, as certain occupations, pulmonary disease, constipation, and obstruction to urination, are all predisposing causes. Trauma from ill-applied trusses, inflammation, and bands in the sac all may produce it. Volvulus of the contained loop may occur.

Mechanism.—Several theories have been advanced as to the manner in which the pressure is brought about and exerted upon the contained bowel. Undoubtedly the exact mechanism varies in different cases, and it is a combination of factors rather than any single one that produces the result. Among the various theories advanced, the following are the more important: 1st. Elasticity of the ring (Richter). 2d. Compression of the efferent by the distended afferent end of the loop (Lossen). 3d. Angulation of the distal end at the margin of the orifice (Scarpa). 4th. Fæcal impaction. 5th. Torsion or volvulus of the loop (de Roubai). Whatever the cause it must first interfere with the return circulation, producing congestion which increases the bulk of the contained gut and thus augments the pressure. The condition thus tends always to increase itself.

Violent peristaltic efforts of the intestine to force its contents onward increase the pressure at the point of constriction. The mesentery becomes swollen with the intestine and at the same time is put upon the stretch by the excessive peristalsis. This stretching of the mesentery may produce interference with the circulation in the mesentery and gut on the abdominal side of the constriction, which accounts for the not infrequent circulatory disturbances observed proximal to the site of constriction. The latter may also be due to the nipping of the mesenteric vessels supplying gut which is not in the hernial sac. Furthermore, volvulus of intestine lying in the abdominal cavity may be caused by the anchoring of a loop in the hernial sac. The intestine in the sac then represents only a portion of that involved.

Anatomical Changes.—The strangulated intestine passes through stages which can be conveniently stated as (1st) congestion; (2d) inflammation; (3d) gangrene. The rapidity of sequence of these stages depends upon the degree to which the circulation is interfered with. As the return circulation is the first to be interfered with, the first change is an engorgement of the vessels. The walls of the intestine become œdematous and change in color, becoming dark red or purple, and black or grayish-black as gangrene supervenes.

The peritoneum loses its glistening appearance and becomes dull and granular as its vitality disappears. At the site of constriction, usually the neck of the sac, there is a deep furrow which is as a rule grayish in color. The intestine becomes cold, loses its power of contractility, and is distended with gas. As these changes progress there is an exudate of serum, later becoming bloody, into the sac; and a migration of pathogenic germs, notably the B. coli communis and varieties of streptococci and staphylococci, takes place through the walls of the gut. The local peritonitis in the sac may extend to the general cavity and produce a spreading peritonitis, or it may be shut off by adhesions. On the other hand, if the vitality of the bowel within the abdomen be impaired, from the causes already stated or from a progressive thrombosis of the vessels, peritonitis may be primarily instituted within the abdomen itself. If the strangulation be due to inflammation of an irreducible hernia, the sequence of events is slightly changed in that the stage of inflammation precedes that of congestion. When gangrene ensues it may occur locally in small patches at the seat of constriction or at the convexity of the loop, or the whole loop may slough. With the gangrene there is an escape of the contents of the bowel. The skin over the sac at first is not involved, but later the tissues covering the sac become infiltrated and œdematous. Finally, an abscess may form and burst and a spontaneous artifical anus result. This is more likely to be the outcome in cases of partial enterocele (Richter's hernia), when only a portion of the circumference of the gut is nipped, and explains the manner in which spontaneous cures may sometimes occur.

The extent of gangrene varies from a portion of the circumference of the bowel to several feet.

The period elapsing between the onset of strangulation and the occurrence of gangrene varies considerably, from four hours to several days, but is rarely less than twenty-four hours. The presence of omentum in the sac delays the onset of gangrene.

Symptoms.—The symptoms of a strangulated hernia are conveniently divided into the general and the local. The general symptoms are practically those of acute intestinal obstruction in contradistinction to those of an obstructed hernia, which are rather those of chronic intestinal obstruction. They are pain, vomiting, complete constipation, and collapse. To these may be added those of general peritonitis.

Pain is of two varieties: a severe colicky pain felt in the region of the umbilicus, which may be constant but more often remittent, and an aching pain at the hernial site. After the onset of gangrene the pain may disappear.

Vomiting is an important symptom. It is as a rule persistent from the moment of strangulation. The contents of the stomach are first expelled, then those of the upper part of the small intestine, and finally the vomitus becomes stercoraceous. It is not accompanied by marked nausea, and is remarkable on account of the quantities expelled. In later stages it becomes regurgitant and there may be hiccough. It may be absent in Richter's hernia, and it may cease on the advent of gangrene. Constipation is complete, no gas or fæces being passed. However, the bowel may be emptied below the seat of strangulation, and if the strangulation is high up in the small intestine a considerable quantity of fæces may be expelled. Also in Richter's hernia, constipation is not the rule and there may even be diarrhœa. The degree of abdominal distention is likewise dependent upon the site of strangulation. If this is located high up in the small intestine it is relatively slight, while if the large intestine is implicated it is great. It is at first accompanied by excessive peristalsis, but later the paralytic meteorism of peritonitis may be present.

Collapse is usually profound, although it may be delayed for several hours. The pulse becomes weak and thready, the temperature is subnormal, the extremities are cold and moist, and the facies abdominis is marked. When inflammation sets in, the temperature usually rises, but it seldom reaches a high level. The duration of life averages from five to seven days. In the aged the symptoms often are not marked, the course presenting an asthenic type in which some of the classic symptoms may be wholly absent. The symptoms at the site of the hernia are pain, irreducibility, loss of impulse, tenderness, dulness, and the absence of gurgling. The hernial protrusion may be so small as readily to escape notice, and it must be remembered that the absence of a history of hernia does not exclude, inasmuch as a hernia may become strangulated on its first appearance. The attention of the patient is usually attracted to the hernia by the presence of pain. The local pain may be masked, however, by the general abdominal pains.

The chief value of irreducibility as a sign of strangulation is in herniæ that have previously been reducible. It may be absolute or relative. Tenseness, dulness, loss of impulse and the absence of gurgling are all due to the same causes, *i.e.*, fixation and swelling of the contents of the sac and the exudation of fluid within it.

In certain forms of strangulated hernia the characteristic symptoms may be masked or modified.

The following classification, slightly modified from that of Eccles,[2] will serve to indicate the sources of ambiguity.

I. Cases in which the peculiarities are dependent upon the contents of the sac.

1. Strangulation of a portion of the bowel.

(1) Partial enterocele (Richter's hernia).

(2) Strangulation of the vermiform appendix.

(3) Strangulation of Meckel's diverticulum (Littré's hernia).

2. Strangulation within the body of the sac.

(1) By bands, adhesions, apertures in omentum, etc.

(2) By kinking or volvulus.

II. Cases in which the peculiarities are dependent upon the sac.

1. Strangulation within a loculus or pouch of the sac.

In cases of strangulation of a portion of the bowel the general symptoms as a rule are not marked, while the local symptoms may be characteristic. On the other hand, the remainder of the classified cases present the usual general symptoms, while the local symptoms may be markedly modified. The differences in the local symptoms are due to the fact that the entire hernia is not necessarily irreducible, and there may be impulse, tympany, and gurgling at a portion of the protrusion.

In the following groups of cases errors of diagnosis as to the site of strangulation, or as to whether it is present or not, may arise (modified from Eccles[2]).

I. Cases with multiple herniæ.

1. Two (or more) herniæ, one irreducible and the other strangulated.

2. Two herniæ, one concealing the other.

3. An inguinal and a femoral hernia on the same side, one strangulated and the other not.

II. Cases with irreducible hernia in which the obstruction or strangulation is within the abdomen and not at the site of the hernia.

In cases of multiple herniæ the local symptoms as a rule are sufficient to determine the site of strangulation. In infants, inasmuch as they are unable to direct attention to the local condition and as they are frequently subject to attacks of vomiting and colic, the diagnosis may be delayed. In them continued vomiting should lead to a thorough examination of all hernial sites. The differential diagnosis lies chiefly between strangulated and obstructed or inflamed hernia. Other conditions which may simulate strangulated hernia are inguinal adenitis, acute epididymitis or orchitis, and severe colic, peritonitis, or the uncontrollable vomiting of pregnancy in conjunction with a hernia.

Prognosis.—The prognosis in untreated cases is uniformly bad, with the exception of the exceedingly few cases that end in recovery with the spontaneous formation of an artificial anus. The mortality following taxis and that associated with herniotomy manifestly cannot be compared, inasmuch as the conditions found in many cases successfully operated upon would absolutely contraindicate the employment of taxis, and also because cases in which taxis proves successful would in all probability be successfully treated by operation.

The statistics of Frickhoffer[1] in regard to cases in which taxis has been apparently successful give in 308 cases of femoral hernia a mortality of 14.9 per cent., and in 518 cases of inguinal hernia one of 7.8 per cent. The statistics of herniotomy show a mortality that varies from 10 per cent. to 12 per cent. in cases in which the strangulation has existed twenty-four hours or less, to 50 per cent. in cases in which it has existed over three days. The risk of herniotomy when the gut is still returnable is comparatively slight. In gangrenous hernia the mortality depends largely upon the method of treatment of the intestine (see Treatment).

In a total of 354 cases of gangrenous hernia, collected by Gibson,[8] 120 were fatal, a mortality of 34 per cent. Of these 354 cases, 96 were of the inguinal variety, with 25 deaths (mortality: 26 per cent.); 188 were of the femoral variety, with 69 deaths (mortality: 37 per cent.); 22 were of the umbilical and 2 of the ventral variety, with 16 deaths (mortality: 67 per cent.); and 7 belonged to the obturator variety, with 6 deaths (mortality: 86 per cent.). By these statistics it will be seen that the mortality of femoral hernia is greater than that of the inguinal form, and the mortality of umbilical hernia is greater than that of femoral hernia.

Treatment.—The treatment of strangulated hernia is by means either of *taxis* or of *herniotomy.*

Taxis is the reduction of the protrusion by manipulation. It is best performed with the aid of a general anæsthetic, and the operator should be prepared to resort at once to herniotomy if his efforts at reduction fail. In inguinal and femoral hernia the parts are relaxed by flexing the thigh on the pelvis and rotating it in an inward direction. Placing the patient in a position of slight inversion, *i.e.*, with the head lower than the pelvis, is permissible.

The neck of the sac is then grasped with the left hand and gentle efforts are made with the right hand to press the contents back. Pressure should be exerted in the direction of the canal; upward, outward, and backward in inguinal and backward and upward in femoral hernia. The efforts should never be prolonged for more than five minutes and roughness is distinctly contraindicated.

Success is determined by the complete disappearance of the hernia, and by the fact that the surgeon can pass his finger through the ring.

Taxis is contraindicated in the following conditions:

1. When it has already failed.
2. When the superficial tissues are inflamed.
3. When there is reason to suppose that the intestine may be gangrenous.
4. When strangulation has existed for twenty-four hours.
5. When the hernia has been previously irreducible.
6. When there is great prostration.

The dangers of taxis are:

1. Injury or rupture of the intestine.
2. The return of gangrenous intestine to the abdominal cavity.

3. The transference of septic fluid from the sac into the general peritoneal cavity.
4. "Reduction *en masse.*"

Reduction *en masse* is rare, is more frequent in inguinal hernia, and is practically the conversion of the hernia into a form of interstitial hernia; the sac and its contents being forced into a position between the transversalis fascia and the remainder of the abdominal wall, while the constriction still remains at the neck (Fig. 2622). The sac may be ruptured and its contents escape into its new position; or only part of the sac may be reduced.

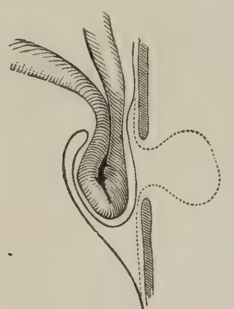

FIG. 2622.

In modern surgery taxis is resorted to with constantly diminishing frequency, most surgeons now performing herniotomy at once.

Herniotomy and *kelotomy* are the terms applied to the operation for the relief of strangulated hernia. This operation possesses the advantage over taxis of avoiding its dangers, of permitting inspection of the intestine, and of affording an opportunity for the radical cure of the hernia.

The steps in the operation are:
1. The exposure of the sac.
2. Opening of the sac and relief of the constriction.
3. Treatment of the contents.
4. Closure of the wound.

The sac is exposed by an incision similar to that which would be employed in an operation for radical cure. The incision should be made in such a manner as to expose well the neck of the sac, and it may have to be prolonged in order to afford room for resection of the bowel. The sac is recognized by its dark color and its gliding over the contents. It is opened by pinching it up with forceps so as to form a fold which can be incised without injury to the contents. When an opening has been made, the fluid which escapes will be clear and odorless, although it may be bloody, if the gut is sound; or it will be cloudy, purulent, or feculent, if the vitality of the gut has become impaired. The interior of the sac and the contents are then thoroughly washed with normal salt solution to lessen the chances of contamination and the constriction is sought for and divided.

Inasmuch as the constriction is usually caused by bands of fascia which lie outside the sac, division is best done from without, and not from within, as was formerly taught by the old school. It may be necessary, however, in some femoral herniæ to divide it from within, which is done by cutting upward with the herniotome or blunt-pointed bistoury or by use of a director. The constriction having been freely divided the gut must be gently drawn out to expose the efferent and afferent portions, especially the latter, in order to observe their condition, since changes in their nutrition may have occurred for a considerable distance within the abdomen. If the condition of the gut is satisfactory it is returned to the abdomen and the wound is closed as in the operation for radical cure of a hernia of the same variety.

The gut is returned if its peritoneal coat is smooth and glistening, if its color is not black or gray, even though it may be dark red or purple, if the fluid in the sac is odorless and clear, and especially if it has retained the power of contractility in all its parts. It must not be returned if the peritoneum has a granular aspect, if the fluid is cloudy and foul, or if the gut is cold and flabby and has lost its contractility. If there is doubt, the constriction having been freely relieved, the bowel may be surrounded with compresses wet in warm normal salt solution, for several minutes, and its condition again noted. In cases of exceptional doubt it may be thus left for twenty-four hours. Very small areas of gangrene may be excised and the edges of the resulting perforation turned in with Lembert sutures.

If the gut is not in a returnable condition, there are two methods of treatment applicable: 1. Resection and immediate reunion. 2. Formation of an artificial anus. In the performance of the latter the gut is either fixed by a few sutures to the margins of the wound and opened to relieve the obstruction, or it is resected and the ends are sutured to the wound.

In the choice between resection and immediate reunion, and the formation of an artificial anus, the operator must take into consideration the condition of the patient and his own skill as an intestinal surgeon. According to Hofmeister,[3] the decision to form an artificial anus is tantamount to the expression that the case is otherwise hopeless.

As the following statistics in regard to gangrenous hernia show, the treatment by primary resection and immediate reunion is the most successful.

Compiler or operator.	ARTIFICIAL ANUS.			PRIMARY RESECTION AND REUNION.		
	Cases.	Deaths.	Mortality, per cent.	Cases.	Deaths.	Mortality, per cent.
Zeidler[4] (1892)..........	287	213	74.22	289	142	49.13
Mikulicz[5].....	94	72	76.6	68	32	47.1
Hofmeister[6] (1900)......	167	101	60.5	214	99	46.0
Petersen (up to 1898)....	17	10	57.0	16	8	50.0
Petersen (since 1898)....	5	5	100.0	12	1	8.3
Petersen[7] (total)........	22	15	68.2	28	9	32.14
Gibson[8] (1900)..........	101	53	52.5	226	58	26.0

Of these series Gibson's are the most comprehensive and argue strongly in favor of resection and reunion. His statistics in regard to the formation of an artificial anus with and without resection of the gangrenous intestine show a very slight advantage in favor of resection. In twenty cases collected by him in which the gangrenous portion was invaginated, three patients died—a mortality of fourteen per cent.

The large mortality following the formation of an artificial anus is due not only to the immediate condition, but also to asthenia if the anus is situated high up in the tract, and to the subsequent measures taken to cure the artificial anus. The mortality of the operation for relief of artificial anus following herniotomy is in the neighborhood of twenty-five per cent.

The chief considerations to be observed in regard to the treatment of gangrenous hernia are: the use of local anæsthesia if feasible; the employment of a large wound (hernio-laparotomy), enabling the operator to return the intestine easily and visibly, thus avoiding kinking; the emptying of the intestine so far as possible; wide resection, the amount removed depending largely on the condition of the mucous membrane; open treatment of the wound by tamponade when peritonitis is present, or if the condition of the returned bowel is still suspicious.

For the technique of intestinal resection the reader is referred to special articles on that subject. A fatal outcome in herniotomy is due to one or more of the following causes: 1. Shock. 2. Return of damaged intestine (insufficient resection). 3. Extension of an existing peritonitis, or one due to leakage (faulty suture). 4. Kinking or twisting of the returned loop. 5. Exhaustion (artificial anus).

The after-treatment does not differ from that employed after other operations upon the intestinal tract. For the first few days the bowels are best opened by enemata.

ANATOMICAL VARIETIES OF HERNIA.

INGUINAL HERNIA.—This term includes all herniæ into or through the inguinal canal.

Anatomy.—For the detailed anatomy of this region the reader is referred to special treatises. There are, however, certain considerations which are not generally made clear, and which have considerable bearing especially upon the methods of radical cure. In the second month of fœtal life a process, the *processus vaginalis peritonei,* is found evaginated from the peritoneum of the body cavity and accompanying the gubernaculum to that part of the skin of the inguinal region which becomes the scrotum in the male and the labium majus in the female.

Later the testicle descends alongside of this process to the scrotum, and the distal portion of the process forms the *tunica vaginalis testis.* The proximal portion ordinarily becomes obliterated, but if it remains open the tunica vaginalis continues in communication with the peritoneum, and a portion of the abdominal contents may descend through it. Such a protrusion is known as a congenital hernia, even if it does not descend until adult life. If the process remains open in the female it is known as the canal of Nuck.

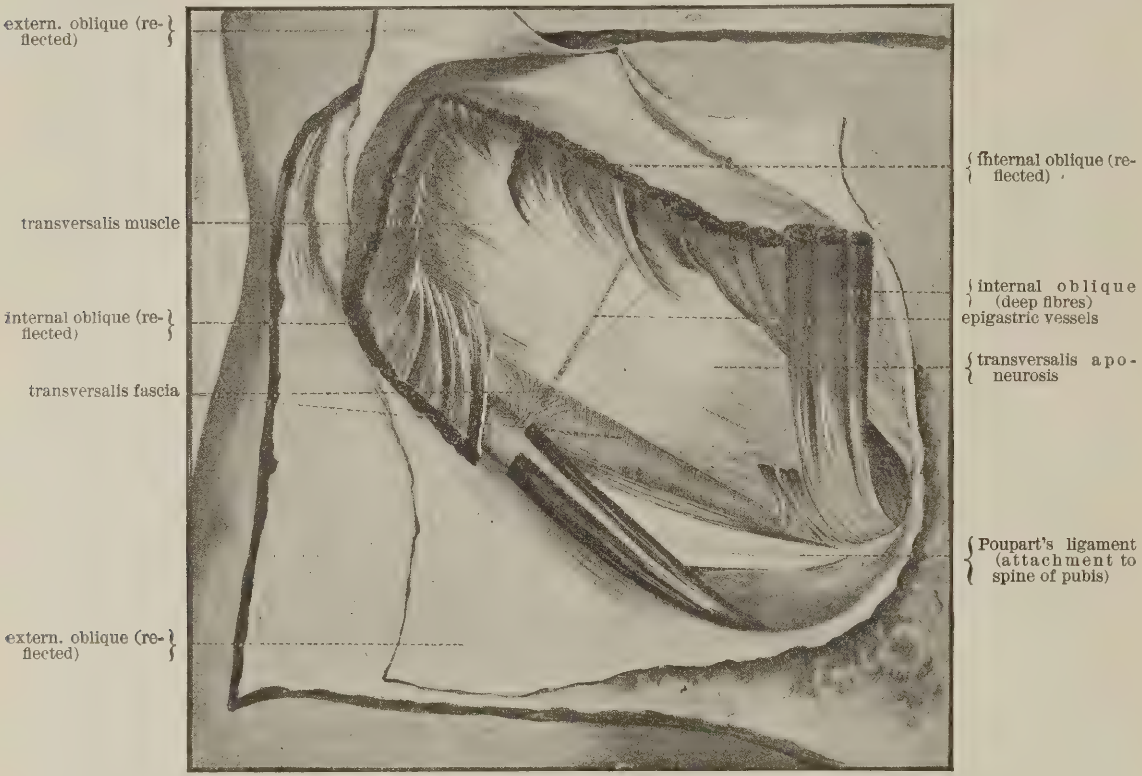
extern. oblique (reflected)
transversalis muscle
internal oblique (reflected)
transversalis fascia
extern. oblique (reflected)
internal oblique (reflected)
internal oblique (deep fibres)
epigastric vessels
transversalis aponeurosis
Poupart's ligament (attachment to spine of pubis)

FIG. 2623.

Incomplete or partial obliteration of the process gives rise to cystic swellings, known as hydroceles of the cord or of the round ligaments, as may be.

The abdominal wall in this region, omitting the superficial structures, consists of the following muscular and aponeurotic layers from without in: the aponeurosis of the external oblique, the internal oblique and transversalis muscles, and the transversalis fascia. At the mesal part of this region the rectus abdominis is inserted into the pubis on a plane dorsad to the structures enumerated, with the exception of the transversalis fascia, which sends a prolongation over the dorsal surface of the muscle.

The general arrangement of these structures is shown in the accompaning figures (Figs. 2623 and 2624). The inguinal canal, which contains the gubernaculum and processus vaginalis peritonei in the fœtus and the spermatic cord or round ligament in the adult, and through which the testicle passes in its descent, is found between these structures. Its commencement, the internal abdominal ring, is an aperture in the transversalis fascia normally just large enough to permit the passage of the cord. Its termination, the external abdominal ring, is a slit-like aperture in the aponeurosis of the external oblique muscle. The internal ring is situated about 4 cm. laterad to the spine of the pubis and about 1 to 1.5 cm. above Poupart's ligament, being suspended as it were in the transversalis fascia (Fig. 2624), which is developed in curving fibres on its mesal and lower aspect, forming the inguinal ligaments of Henle. It lies thus about half-way between the anterior superior spine of the ilium and the spine of the pubis, and a finger's breadth above Poupart's ligament. The deep epigastric artery passes upward at the mesal border of the ring between the transversalis fascia and the peritoneum. The external ring lies just above and laterad to the spine of the pubis.

The inguinal canal is about 3.5 cm. long and is slightly longer in the female than in the male. At its commencement its ventral wall is formed by the thick fleshy fibres of the internal oblique and the transversalis muscles, and its dorsal wall by the transversalis fascia. At about its middle its dorsal wall is still the transversalis fascia, but the internal oblique and transversalis muscles are above it and its ventral wall is formed by the aponeurosis of the external oblique. At its termination it escapes through the external oblique, and its dorsal wall is here formed by transversalis fascia, which for the last centimetre is strengthened by the conjoined tendon and the triangular ligament. In the final two-thirds of its course its floor is formed by the shelf of Poupart's as it broadens into Gimbernat's ligament. The greater part of the dorsal wall is thus seen to be formed by the transversalis fascia, and the importance of this as a safeguard cannot be overestimated. It is in fact a special development of the transversalis fascia, and by some it has been described as a part of the conjoined tendon, although it is entirely distinct from this structure. Its mesal portion consists of strong vertical fibres, its lateral of the fibres before mentioned as curving about the internal ring. Between these stronger portions is a weaker one, lying as a rule on the mesal side of the deep epigastric artery, and at this part direct inguinal herniæ occur (Fig. 2624). The transversalis muscle is very poorly developed in this region, and consists chiefly of an aponeurosis, the fibres of which pass horizontally across to their insertion in the ventral rectus sheath, and as a rule are wanting for some distance above Poupart's ligament (Fig. 2623). The internal oblique muscle, on the other hand, consists of a thick, fleshy mass of fibres which, unless displaced by a hernia or ill developed, completely protect the internal ring and pass to their insertion with a general direction parallel to Poupart's ligament, only rising sufficiently to allow the cord to pass below them. The conjoined tendon consists of a few fasciculi derived from the opposed surfaces of the internal oblique and transversalis muscles, and passes on the deep surface of the former muscle to be inserted by tendinous fibres to the crest and ilio-pectineal line. This structure is wholly concealed by the internal oblique, and its insertion seldom extends for more than a centimetre laterad to the spine of the pubis.[9] Although given considerable prominence in most text-books, it is a negligible factor in procedures for the radical cure of hernia.

An oblique inguinal hernia is enclosed in the same layers of fascia as the spermatic cord. These layers from within out are: the infundibuliform fascia derived from the transversalis fascia; the cremasteric fascia and muscle derived from the internal oblique; and the intercolumnar fascia derived from the external oblique. These layers must be divided in separating the sac from the cord. The fascial coverings of a direct hernia are the same, with the exception that the transversalis fascia itself is substituted for its infundibuliform process.

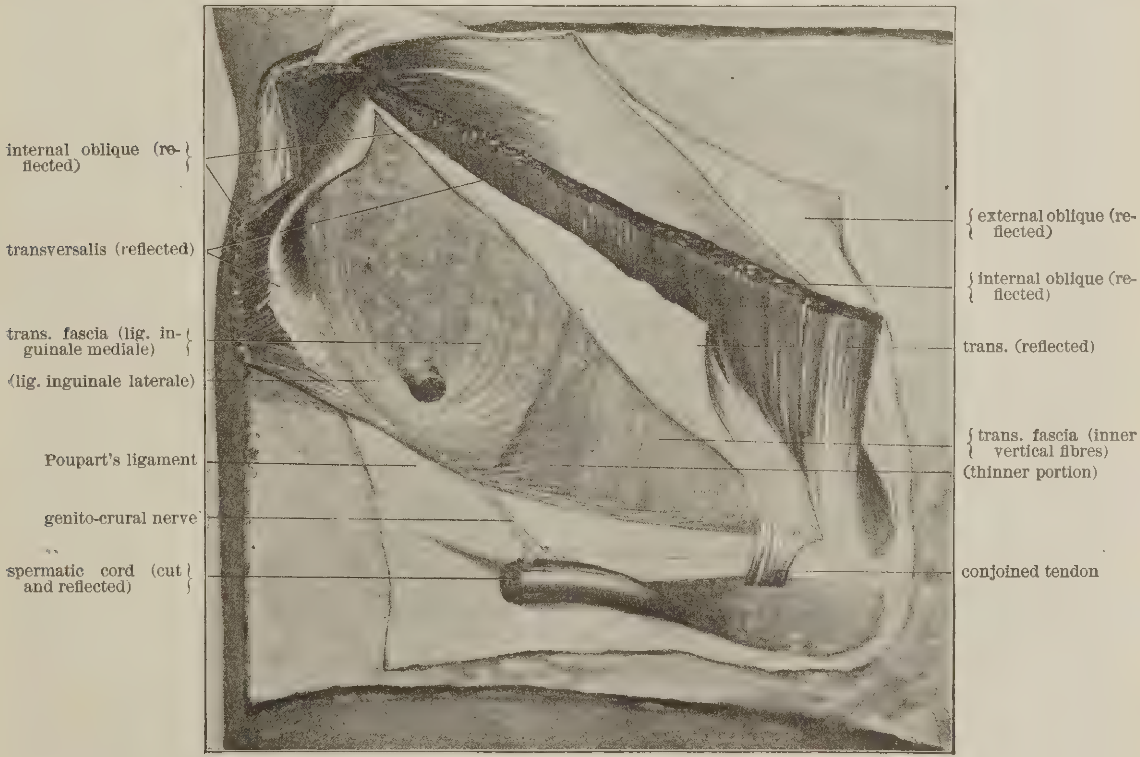
internal oblique (reflected)
transversalis (reflected)
trans. fascia (lig. inguinale mediale)
(lig. inguinale laterale)
Poupart's ligament
genito-crural nerve
spermatic cord (cut and reflected)
external oblique (reflected)
internal oblique (reflected)
trans. (reflected)
trans. fascia (inner vertical fibres)
(thinner portion)
conjoined tendon

FIG. 2624.

The relations of the spermatic cord to the sac are important. The structures of the cord are usually somewhat spread out on the surface of the hernia unless the latter is small or a direct one. The vessels lie on the lateral and the vas deferens on the latero-dorsal aspect of the sac. In a direct hernia the entire cord is on the lateral aspect of the sac. In congenital hernia the cord is more closely adherent to the sac than in acquired herniæ. The importance of the peritoneal fossæ on the internal abdominal wall as etiological factors in the production of hernia seems to the writer to be exaggerated. The presence of muscular or fascial weaknesses or dimples is of far greater importance, inasmuch as the peritoneum is a highly elastic and distensible membrane, and when unsupported by other structures offers little resistance to pressure from within. For the same reason the treatment of the neck of the sac is of minor importance in the operation for radical cure.

Varieties of Inguinal Hernia.—Inguinal herniæ are divided into *direct,* which is always acquired, and *indirect* or *oblique,* which may be congenital or acquired (see Anatomy). In a direct hernia the protrusion is mesal, while in an indirect hernia it is lateral to the deep epigastric vessels. If the protrusion passes through the external abdominal ring into the scrotum or labium majus it is termed a complete or scrotal hernia; if not, an incomplete hernia or bubonocele.

Direct Inguinal Hernia.—Direct inguinal herniæ constitute seven per cent. of all inguinal herniæ. They are more common in men than in women and are seldom seen in children. They are always acquired. They are seldom complete and may usually be recognized by their globular shape and by the fact that they appear to bulge directly through the abdominal wall.

Indirect Inguinal Hernia constitutes the greater part (ninety-three per cent.) of inguinal herniæ. The hernia may descend into the unobliterated processus vaginalis either in the male or in the female, being then called congenital hernia (Fig. 2625, *A*); or its sac may be formed by the protruded peritoneum of the abdomen—acquired hernia. The proportion of congenital to acquired herniæ is difficult to state, as the diagnosis is made only by operation. A study by Bull and Coley[10] of five hundred cases of inguinal hernia operated upon in children under fourteen years of age showed that less than fifty per cent. were congenital.

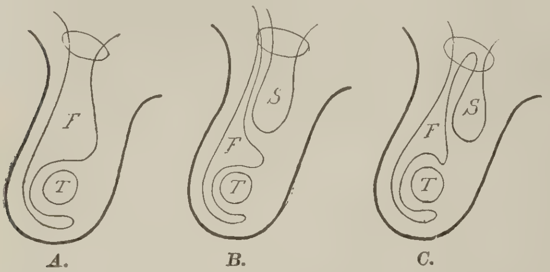

Fig. 2625.—Formation of Sac in Congenital and Infantile Hernia. *A*, Congenital hernia; *B* and *C*, infantile hernia; *F*, funicular process; *S*, sac; *T*, testicle.

A form of hernia known as *infantile hernia*, although always acquired, is sometimes confounded with congenital hernia. The hernial sac in these cases is formed from the parietal peritoneum and is pushed down alongside of an open or partially obliterated funicular process; the different varieties of this form depend upon the extent and the site of the obliteration (Fig. 2625, *B* and *C*). Since the unobliterated funicular process is often spread out over the hernial sac, the latter appears as a sac within a sac; hence the term encysted hernia.

Interstitial Hernia is a form of inguinal hernia in which the protrusion insinuates itself between the layers of the abdominal wall. According to Langdon,[11] the frequency of interstitial hernia is 1 in 1,100. It is relatively more common in females than in males, forming 0.13 per cent. of all inguinal herniæ in males and 0.61 per cent. in females.[1]

Three varieties are recognized. In order of frequency they are: (1) Between the internal oblique and the aponeurosis of the external oblique; (2) between the aponeurosis of the external oblique and the skin; and (3) between the peritoneum and the transversalis fascia (properitoneal hernia). The first two varieties present an external swelling, while no visible or palpable tumor is found in the last variety. In the majority of the cases of the last variety there is also a scrotal or labial hernia. Such an accompaniment is seldom observed in the first two varieties. In fact the sac of a properitoneal hernia is usually a diverticulum of the sac of a complete hernia; and herein lies its danger, since a false idea of security may follow reduction of the complete portion.

The causes contributing to the production of interstitial hernia are efforts at reduction, giving rise generally to the properitoneal form; and errors in development, namely, non-descent of the testicle or incomplete closure of the canal of Nuck. Macready states that in 67 per cent. of the cases in males the testicle was wholly retained or only partially descended. According to Langdon,[11] in 42 cases of interstitial herniæ in males in only 2 were the testicles in normal position in the scrotum.

The second and third varieties may acquire very large dimensions. Inasmuch as it is difficult to prevent the return of an interstitial hernia by a truss, operation is as a rule indicated.

Diagnosis of Inguinal Hernia.—The subjective symptoms are pain, which is present in ninety-six per cent. of all cases in the early stages, and later a sense of fulness and discomfort. The chief objective sign is a tumor, which as a rule disappears when the patient lies down but returns upon his standing, coughing, or crying. Impulse is present in reducible forms, and in complete hernia the contents may be felt to descend by the finger introduced into the canal.

Incomplete hernia or bubonocele must be differentiated from femoral hernia, hydrocele of the cord or canal of Nuck, inflammatory conditions and new growths of the inguinal glands and cord, psoas abscess, and undescended testicle. It is distinguished from femoral hernia by its relation to Poupart's ligament and the spine of the pubis; from hydrocele by the irreducibility, circumscription, and fluctuation of the latter; and from psoas abscess by the presence in the latter condition of a deep-seated swelling above Poupart's ligament, between which and the visible protrusion fluctuation can be obtained.

The conditions most commonly confounded with complete inguinal hernia are hydrocele, hæmatocele, varicocele, and tumors or inflammatory conditions of the testicle or epididymis. The statements of the patient as to the position and growth of the swelling at its incidence, taken with the characteristic signs of the several conditions, will serve, as a rule, to make the diagnosis evident.

Treatment of Inguinal Hernia. (For treatment by truss see "Mechanical Treatment of Hernia.")

Radical Cure of Inguinal Hernia.—The operative methods devised for the cure of inguinal hernia are so numerous, and so many have become obsolete, that the reader must be referred to special treatises for the details of those operations which have a historical interest only.

The success with which radical cure is performed at the present time is due primarily to the almost uniform aseptic healing obtained, and, secondly, to the improvements in technique and method. The aim of present methods is to secure the least possible scar formation, and the production of a muscular contractile barrier against future relapse.

Methods depending upon the use of foreign materials to form an obturator have been advanced in the last few years but have not become popular, largely on account of the inherent difficulties in getting such substances to remain within the tissues of the body without giving rise to trouble.

The methods most commonly in use at the present time and which have given the best results are the following: Bassini's (1888), Halsted's (1890), Kocher's (1892), and Macewen's (1886).

The Bassini operation is the favorite one at present. According to a recent writer,[12] about ninety-five per cent. of all operations for inguinal hernia are being done by this method or slight modifications of it. The steps of the operation are as follows: The incision is made parallel with Poupart's ligament and 2 cm. above it, from a point laterad to the internal ring to a point corresponding to the centre of the external ring. The length of the incision is 7 to 9 cm. in adults and shorter in children.

The incision is carried directly to the aponeurosis of the external oblique, and if properly planned should strike it in the line of divergence of the pillars of the external ring. The superficial structures should not be stripped from the aponeurosis since its vitality is thereby impaired. The aponeurosis is then slit in the direction of its fibres for a distance of 5 or 6 cm. from the external ring, care being taken not to wound the underlying structures. The upper lip of the aponeurosis is then stripped from the surface of the internal oblique and the sheath of the rectus for a distance upward of about 3 cm. This separation is important, as it facilitates the bringing down of the fibres of the internal oblique in the final steps of the operation. The tissues covering the cord and sac are similarly stripped from the lower lip of the aponeurosis until the deep surface of Poupart's ligament is well exposed as far as its insertion to the pubic spine. This clearing of the deep surface of the external oblique is best done by blunt dissection, the instrument being swept toward the middle line in the direction of the aponeurotic fibres.

The sac and cord enclosed in their coverings now lie freely exposed, and the second step of the operation, the isolation of the sac, is commenced. A longitudinal incision is made through the cremasteric and transversalis fascia, exposing the sac at its uppermost part (Fig. 2626). The assistant now catches the sac with two toothed forceps, one at each extremity of the incision, and lifts it upward, while the operator seizing the margin of the fascia nearest to him, *i.e.*, on the outer aspect of the sac, draws it away from the sac. The vessels of the cord now appear and must be freed from the sac by a few light touches of the knife. Just beneath the vessels on the outer side of the sac the vas deferens is recognized and is to be freed in a similar manner. The operator in grasping these structures should use smooth forceps and make very light pressure. As the dissection is carried around the sac the assistant shifts his hold, so that at all times the sac is kept tense. If any vessel is divided in this dissection it should be immediately caught and tied so that the field may not be obscured.

The cord now being isolated from the neck of the sac, the finger is inserted between it and the sac from without inward, and curved about the latter; in this way the remaining attachments of the fascia on the inner aspect of the sac are easily stripped off over the point of the finger and the neck is completely circumscribed. The direction of the encircling finger may now be reversed, and the stripping of the sac can be readily accomplished by pushing the cord away from it with gauze, this being aided by a few touches of the knife.

If this procedure is carried out with extreme gentleness subsequent swelling of the cord rarely ensues.

The fundus of the sac having been freed, it is lifted up, and the internal oblique having been retracted to expose the internal ring, the freeing of the sac is carried upward beyond its neck to the point where it flares out into the parietal peritoneum. On the inner aspect of the neck considerable subperitoneal fat will be found, and in large indirect as well as in direct herniæ this may contain the bladder. In congenital hernia the sac is cut in two, the lower portion being of sufficient size to cover the testicle, over which it is sutured.

The third step of the operation comprises opening of the sac, reduction of its contents, and ligation of the neck. Adherent masses of omentum are treated in the usual manner by chain ligation. Ligation of the sac is done by drawing it down as far as possible, its mouth being kept open, and then transfixing its neck as high as possible with a needle carrying heavy catgut. The ligature is tied around each half of the neck separately and then around the entire neck, and the sac is cut off. If the neck is too large for ligation it must be sutured (Fig. 2627).

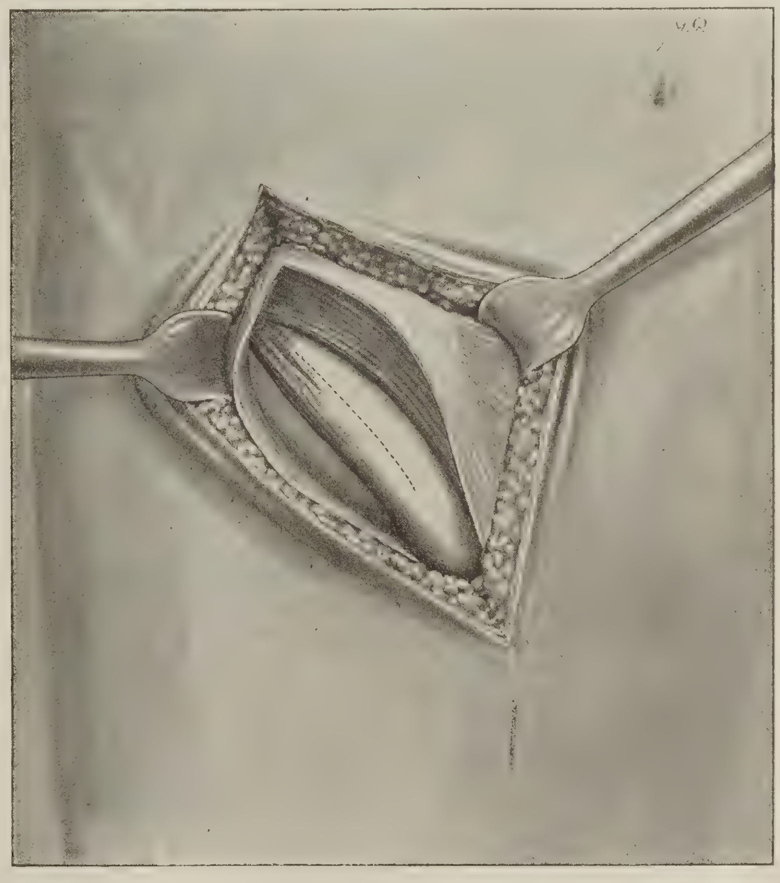

FIG. 2626.—Operation for the Radical Cure of Inguinal Hernia, Bassini's Method. External oblique divided and retracted. Sac in place. Line indicates incision preliminary to separation of cord from sac.

The fourth step is the most important, and herein lies the peculiarity of the Bassini operation, namely, the transplantation of the cord and the suture of the internal oblique* to Poupart's ligament. The cord is first freed from its bed and retracted to the outer part of the incision against the point of origin of the internal oblique from Poupart's ligament.

The first stitch is taken on the inner side of the cord, the needle passing through the whole thickness of the internal oblique 1.5 to 2 cm. from its margin, and then picking up the deep shelving portion of Poupart's ligament. This suture should just touch the cord when it is held at right angles to the wound. Three or four similar sutures are then taken until the spine of the pubis is reached. The last suture takes in the conjoined tendon, and it is often better to include also in it the margin of the rectus, especially when the insertion of the internal oblique does not extend down to the pubic spine (Figs. 2628 and 2629).

The writer, following the example of W. B. Coley, always puts a suture on the outer side of the cord, but he differs from Coley in that he inserts and ties it before the other sutures are introduced, while Coley puts it in last. This suture subserves two purposes: it gives the muscular fibres a lower plane at their origin and it places the point of emergence of the cord at a greater distance from the internal abdominal ring, thus giving the latter additional protection. The sutures should be tied without tension to avoid strangulation of the muscle fibres.

The best suture material is one that will be absorbed in about thirty days. Kangaroo tendon fulfils this condition best, then chromicized catgut. Non-absorbable suture material should not be used, for the tissues sometimes resent its presence and extrude it.

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* The internal oblique muscle is alone mentioned, since it is practically the only structure sutured to the ligament. See the section on Anatomy.

The next step is the suturing of the external oblique, which is done so as to include the cord between it and the internal oblique. A continuous suture is sufficient (Fig. 2630).

The cutaneous incision is then closed with or without drainage, according to the operator's technique.

In the female the steps of the Bassini operation are carried out as in the male, with the exception that in the description of the procedures the round ligament is to be understood whenever the cord is mentioned.

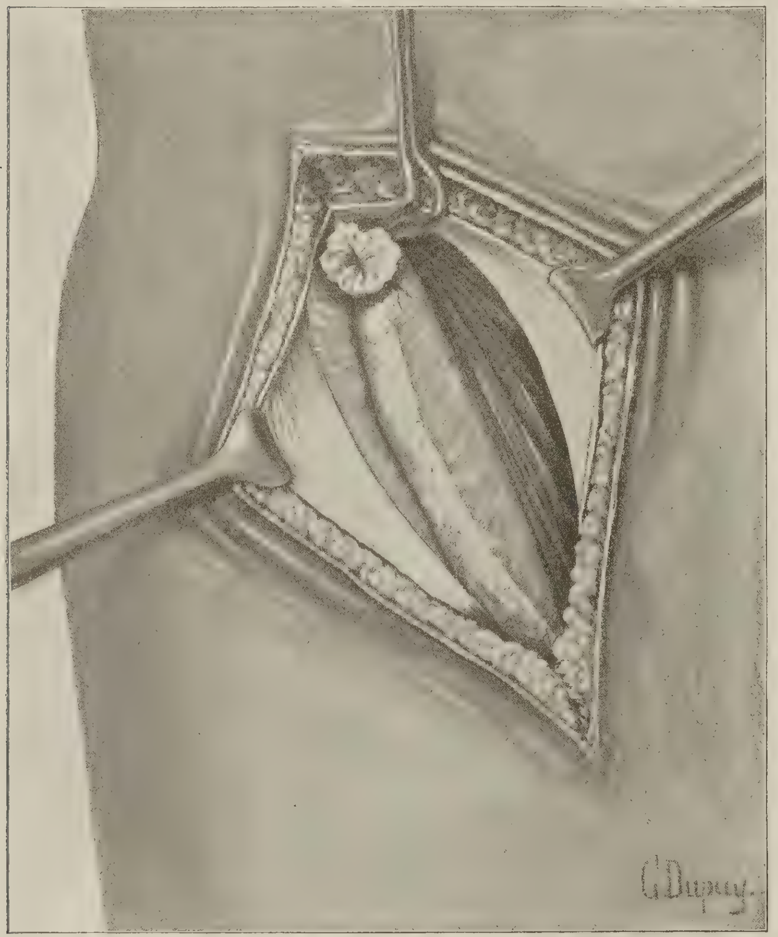

FIG. 2627.—Operation for the Radical Cure of Inguinal Hernia. Bassini's method. The margins of the aponeurosis of the external oblique muscle are retracted horizontally, the internal oblique upward, exposing the site of ligature of sac at the internal ring. The cord lies on the transversalis fascia.

The writer, however, believes it to be a mistake to transplant the round ligament—*vide infra.*

Suture of the muscles without transplantation of the cord has been practised with success by Bull and Coley.[13] The writer has also employed this modification in cases in which the transversalis fascia forming the dorsal wall of the canal was well developed.

Transplantation of the Rectus Muscle.—To meet the condition in which the transversalis fascia forming the dorsal wall of the canal is deficient and the neck of the hernia is very large, Bloodgood[14] devised a most excellent method of transplanting the rectus muscle by slitting its deep or dorsal sheath and drawing it down with the internal oblique to Poupart's ligament. This method is superior to Wölfler's[15] in that the latter operator slits the ventral sheath, thus destroying the insertion of the internal oblique and transversalis at that point. Bloodgood's operation is done in conjunction with the Halsted operation (Fig. 2633). The writer has used his method of opening the sheath, but has stitched the rectus to Poupart's ligament first and brought the internal oblique down in front of it as in the Bassini operation. This procedure is also of value in direct herniæ and when the internal oblique is deficient.

Halsted's Method.[16]—The cutaneous incision, slightly more vertical than the Bassini, having been made, the knife is carried down from the outermost part of the external ring through the aponeurosis of the external oblique, the internal oblique and transversalis muscles, and the transversalis fascia to a point 2 cm. above and slightly lateral to the internal ring. The sac is isolated as high as possible and resected, and the peritoneum is sutured.

The veins of the cord are excised with the exception of one or two. Mattress sutures are then introduced through the entire thickness of the abdominal wall above, with the exception of the skin and peritoneum, and through the transversalis fascia, Poupart's ligament, and the aponeurosis of the external oblique below, the sutures passing beneath the cord, so that when they are tightened the cord lies directly beneath the skin. The sutures are passed so that the distal cut ends of the internal oblique are sutured to Poupart's ligament; thus, as it were, rotating the muscle. Halsted usually employs silver wire (Figs. 2631 and 2632). It is at once seen that there are marked differences between this method and Bassini's. These are: 1. The division of the internal oblique muscle. 2. The transplantation of the cord to a position between cut ends of muscle fibres. 3. The bringing of the cord in a direct line through the entire muscular wall. 4. The excision of the veins. 5. The suture *en masse* of the muscle. These differences are considered by some to be objections.

In fact, in the relapses after Halsted's operation the descent usually occurs along the cord, and in order to obviate this he has lately transplanted the vas deferens alone. The failures of the operation may be attributable to the first three of the points above enumerated. The excision of the veins has, moreover, led to atrophy of the testicle in some cases.

Bloodgood's Method[15] is the same as Halsted's, with the addition, already mentioned, of including the rectus drawn out of its sheath in the lower mattress sutures (Fig. 2633).

The distinguishing features of Kocher's and Macewen's methods consist chiefly in their treatment of the sac.

Kocher's Method.—The aponeurosis of the external oblique is exposed but not divided. The sac is separated from the cord and the separation is carried up to the internal ring where the sac is ligated. A forceps is now thrust through the external oblique aponeurosis above Poupart's ligament and the sac is caught and drawn out of this opening. It is then laid on the surface of the aponeurosis, which is plaited over it with a sort of Lembert suture. These sutures also narrow the canal (Figs. 2634 and 2635).

Macewen's Method.—In this method the sac is folded with a sort of accordion plait by means of a suture, passed from its extremity back and forth through both its walls; the suture is then continued through the transversalis fascia and the muscles above the internal ring in a direction from within outward. The sac thus forms a pad at the ring. The internal ring is then narrowed by suturing the transversalis fascia above it to Poupart's ligament with a mattress suture. Several stitches may be inserted.

The objection to these last two methods is that the sac, when stripped, and especially when ligated, is practically effete material, and it is unsurgical to retain it in the body.

Fowler's Method.—The posterior wall of the canal, consisting of the transversalis fascia and peritoneum, is divided from the internal ring inward to the border of the rectus, and the cord is displaced to this point. The internal ring and the transverse incision are then closed. The incision divides the deep epigastric vessels. The canal may be closed by suture of the internal oblique to Poupart's ligament. This procedure is of particular value in cases associated with undescended testicle, in order to obtain additional length of cord.

Lucas Championnière's Method.—The peculiarity of this method lies in the manner of closing the canal. The muscles and aponeurosis of the upper lip of the wound are brought down over the aponeurosis of the lower lip and retained by mattress sutures, thus producing an overlap.

Remarks.—The chief accidents happening from operations for radical cure are injury of the vas deferens, hemorrhage from omental stumps, to be avoided by including only small masses, pneumonia following the anæsthesia, and sepsis. The occurrence of sepsis largely increases the percentage of relapses.

The mortality is slight. Bull and Coley[17] have found it to be 0.9 per cent. in 10,000 operations performed between 1886 and 1897. In 2,000 later operations the mortality was less than 0.2 per cent. No operations for strangulated hernia are included in these lists.

As a rule children under four years of age and adults over fifty should not be operated upon, inasmuch as many children are cured by the wearing of a truss, and in the aged the hernia can be controlled by truss with less inconvenience than in the younger and more active, while the dangers of operation are greater. Patients with bronchitis should defer operation; but in cases of chronic respiratory diseases, and when the necessity presses, it may be done under local anæsthesia after Cushing's method. As before stated, large irreducible herniæ are not suitable for operation. The best results are obtained in children and young adults.

Choice of Methods.—The most desirable operation is one that combines simplicity with the best results in the hands of a large number of operators.

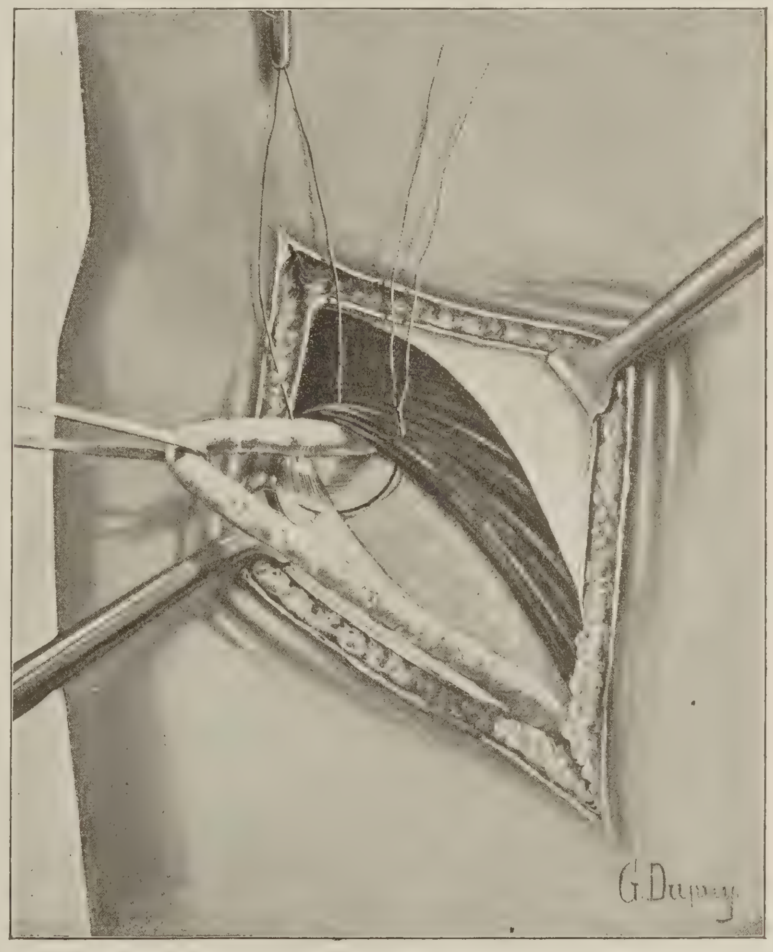

FIG. 2628.—Operation for the Radical Cure of Inguinal Hernia, Bassini's Method. Sac removed, cord drawn aside, and lower fibres of the internal oblique and transversalis muscles stitched to Poupart's ligament from without inward. The transversalis fascia appears at the deepest part of the field of operation.

The Bassini operation seems to meet these requirements better than any other. The percentage of relapses after this operation is probably not greater than 5 in good hands. Coley[18] reports 500 cases traced with 6 relapses only. Galeazzi[19] has collected 1,334 cases operated upon by surgeons out of Italy, with only 2.16 per cent. of relapses. The Halsted method has given 6.5 per cent. relapses, but better results are reported since the veins of the cord have been excised as a routine measure.

The methods of Macewen, Kocher, and Championnière, although each gives as good results in the hands of its originator, have in other hands given much poorer results than the Bassini.

Hernia Associated with Undescended Testicle.—The treatment of this condition is still the subject of considerable controversy. The weight of opinion seems to be that children under ten or twelve years of age should have mechanical treatment if possible, as the truss can be constructed so as to crowd the testicle down. In all cases of operation the testicle should be preserved if possible.

Anchoring of the testicle to the bottom of the scrotum is useless, it should rather be crowded down by passing deep sutures through the deep fascia.

The cord should not be transplanted, as length can be gained otherwise. Possibly Fowler's method would give still greater length.

Operations in children under fourteen years as a rule give the best results, as the testicle is more likely to become scrotal if retained outside the external ring before the changes incident to puberty have taken place.

Post-Operative Treatment.—The patient remains in bed in the reclining position for eighteen days, but is usually able to be up and around on the twenty-first day. This may be stated as the time necessary after operation for any variety of hernia, although sometimes for especial reasons a longer period may be desirable.

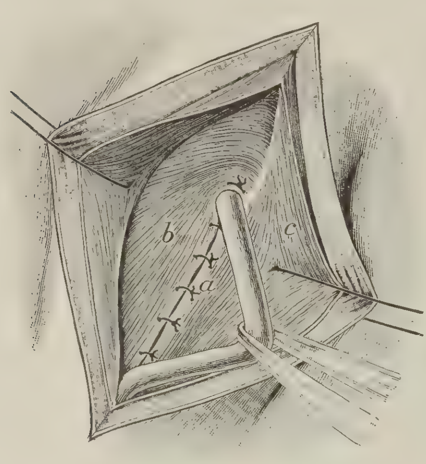

Fig. 2629.

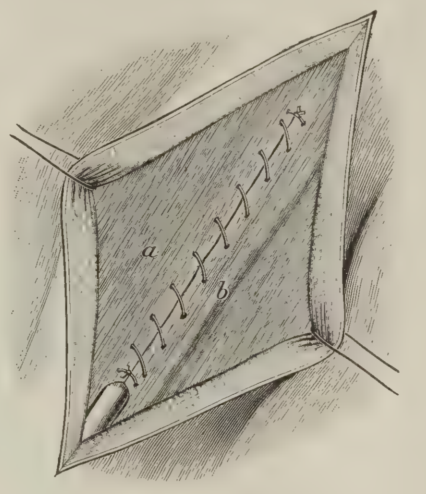

Fig. 2630.

Fig. 2629.—Operation for the Radical Cure of Inguinal Hernia, Bassini's Method. Arched muscular fibres and conjoined tendon (*b*) sewed to Poupart's ligament (*a*). *c*, Aponeurosis of external oblique muscle.

Fig. 2630.—Operation for the Radical Cure of Inguinal Hernia, Bassini's Method. Aponeurosis of external oblique (*a*) sewed with continuous sutures to Poupart's ligament (*b*). (Both from "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

Trusses After Operation.—In children and young adults in whom there is good muscular development and the hernia has not been very large, a truss is unnecessary. Each case has to be judged by itself.

Femoral Hernia.—A femoral hernia is one that descends in or alongside the femoral sheath. The most common form is that in which the gut or omentum descends through the crural or femoral canal, which lies at the mesal side of the femoral vein. In rare cases the hernia may descend in front of the vessels or even on their lateral aspect.

Anatomy.—The femoral sheath is formed by the funnel-shaped process of the transversalis fascia, which is prolonged from the abdominal cavity downward dorsad to Poupart's ligament into the thigh to form the sheath of the femoral vessels. The sheath is too large for the vessels at its commencement but contracts at the saphenous opening to enclose them snugly. Thus a space not occupied by the vessels is left on the mesal side of the vein, and is known as the crural canal. Its ventral boundary is Poupart's ligament; its mesal Gimbernat's ligament; its dorsal the ilio-pectineal line, Cooper's ligament, and the pectineus muscle; and its lateral the femoral vein from which it is separated by a septum of fascia. The space is filled with loose areolar tissue, the septum crurale, and a small lymph node (Fig. 2636).

The deep epigastric artery passes up on the lateral aspect of the canal. In about thirty per cent. of cases the obturator artery is given off from the deep epigastric and then is in relation with the crural canal; although it generally passes downward to the obturator canal on the lateral aspect of the crural canal, yet in three per cent. of all cases it passes down on its mesal aspect and is then subject to injury in herniotomy.

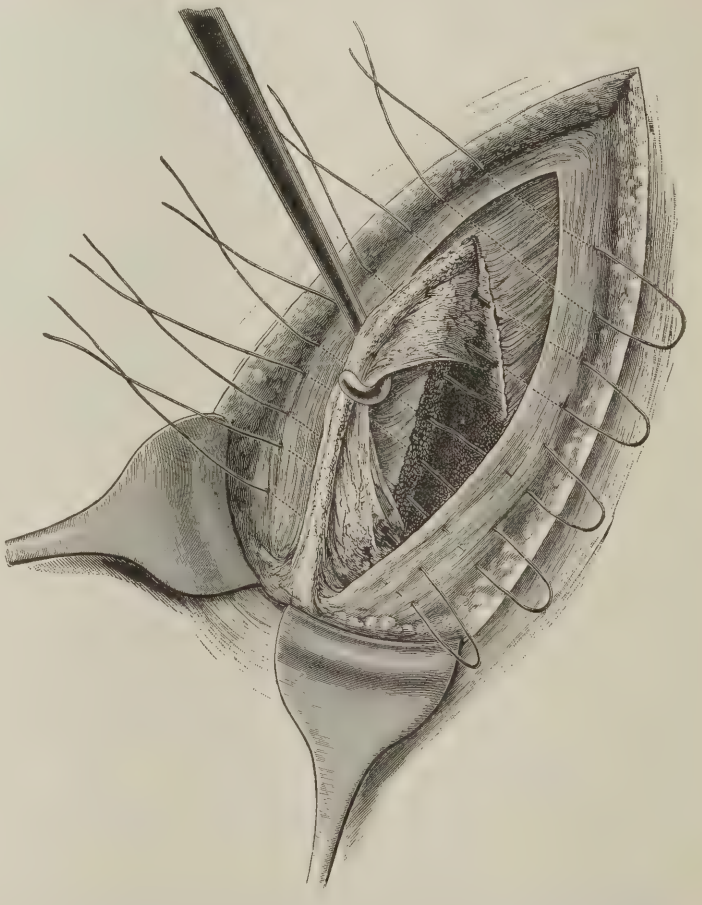

Fig. 2631.—Operation for the Radical Cure of Inguinal Hernia. Halsted's Method. Veins ligatured and resected. Mesocord torn only at its centre. Silver sutures inserted, one above and four below the cord. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

A hernia descending through the crural ring acquires as coverings the peritoneum, the subperitoneal fat which is usually very thick, the septum crurale, the transversalis fascia derived from the femoral sheath, the cribriform fascia, and the superficial fascia and skin.

The protrusion appears in the thigh below the fold formed by Poupart's ligament and below and laterad to the pubic spine. It is usually small and globular or hemispherical in shape. It may extend down the thigh as far as its middle or even farther. Occasionally it turns upward, and passing above Poupart's ligament may be mistaken for an inguinal hernia. Very rarely it may become scrotal or labial. The contents of the sac are more commonly entirely omental than in inguinal hernia. The omentum usually becomes adherent early, especially at the neck of the sac. The intestine is more apt to become strangulated than in inguinal hernia, and gangrene supervenes more quickly.

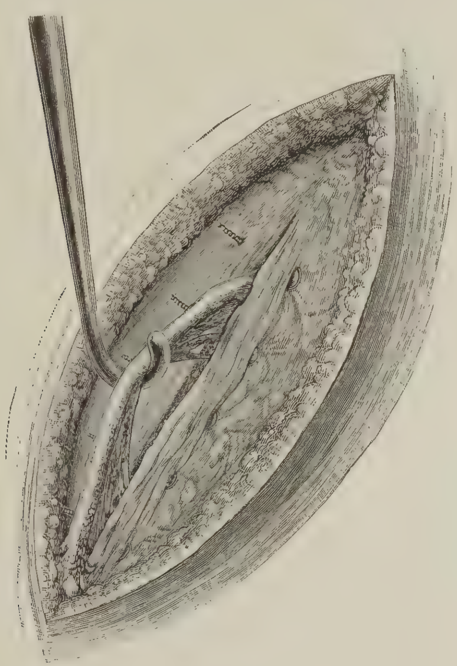

FIG. 2632.—Operation for the Radical Cure of Inguinal Hernia Halsted's Method. Aponeurosis or external oblique closed by silver-wire mattress sutures, ends bent down and buried. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

Occurrence of Femoral Hernia.—Femoral hernia occurs more commonly in women than in men, the ratio being about 3 to 1 in persons under fifty years of age. After this age the proportion of women ruptured decreases so rapidly that the relative frequency in the two sexes is nearly the same. As compared with inguinal hernia the frequency is 1 to 17 according to the statistics of the Hospital for Ruptured and Crippled,[15] according to Macready[1] the ratio is 8 to 92. According to the same author, of 100 men ruptured, 97.5 per cent. have inguinal and 2.5 per cent. femoral hernia. Of 100 women ruptured 60.3 have inguinal and 39.7 per cent. femoral hernia.

As to the period of incidence, it is uncommon in early life, but occurs with greatest frequency in persons between sixteen and fifty years of age.

Causes predisposing to it are weakening of fascia resulting from stretching of the abdominal wall in pregnancy, and the greater size of the crural canal in women.

Diagnosis.—Psoas abscess, inguinal hernia, and saphenous varix may be confounded with reducible femoral hernia, inflammation and new growths of the lymph nodes with the irreducible form. In fat females the diagnosis between femoral and small inguinal herniæ is not always easy.

Treatment.—Unless contraindicated by general considerations, all femoral herniæ should be operated upon for the following reasons: They are more dangerous than inguinal herniæ, they are practically incurable by mechanical means, the operation is simple, and by it permanent cure is nearly always obtained.

Bassini's Method. The sac is exposed by an incision parallel with and slightly below Poupart's ligament. Having been cleared of fat and separated from the canal, the sac is drawn down as far as possible, transfixed, and ligated, after reduction of its contents, and the stump is allowed to recede into the abdominal cavity. Poupart's ligament, the pubic portion of the fascia lata, and the canal having been well cleared of fat, interrupted sutures are now introduced so as to unite Poupart's ligament with the pubic portion of the fascia lata covering the pectineus muscle, care being taken to avoid the femoral vein.

The upper sutures are inserted parallel with Poupart's ligament and pass into the pectineus muscle. The lower sutures unite the falciform process to the pubic portion of the fascia lata. The canal is thus closed (Fig. 2637).

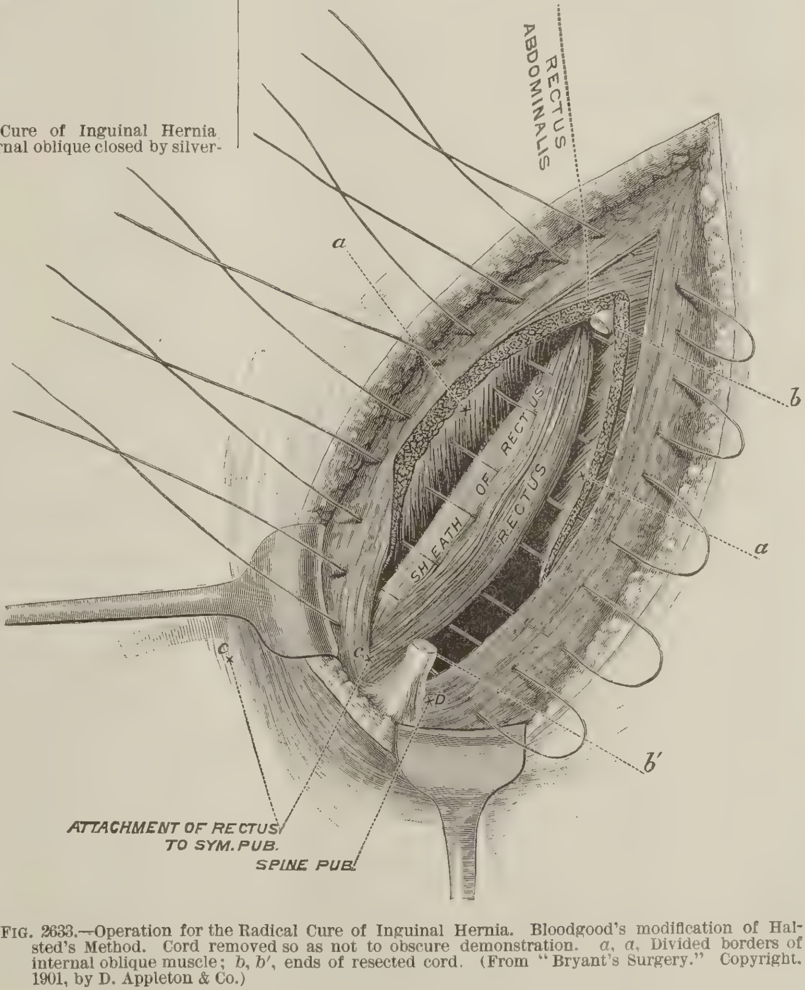

FIG. 2633.—Operation for the Radical Cure of Inguinal Hernia. Bloodgood's modification of Halsted's Method. Cord removed so as not to obscure demonstration. *a*, *a*, Divided borders of internal oblique muscle; *b*, *b′*, ends of resected cord. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

Purse-string Method. The procedure in this method is the same as in the Bassini operation, with the exception that the canal is closed with a single purse-string suture passed in the following manner: A curved needle is introduced through Poupart's ligament and picks up the superficial fibres of the pectineus and its fascia, the falciform process, and finally emerges through Poupart's ligament a short distance from its point of entrance (Fig. 2638). When the canal is very large Bassini's method is preferable.

Gordon's Method. This method has lately been advocated by Bacon.[20] The incision commences 2 cm. above Poupart's ligament and 5 cm. from the pubic spine; it then passes parallel with the ligament to a point opposite the canal, where it turns down over the sac, thus exposing the aponeurosis of the external oblique and the sac. The sac is isolated, its contents are reduced, and then the sac is resected and sutured or ligated flush with the peritoneum. The aponeurosis of the external oblique is split along its fibres, thus opening the inguinal canal, the contents of which are then separated from its lower surface, exposing the deep part of Poupart's ligament. The transversalis fascia forming the femoral sheath is then separated from the ligament, thus opening the femoral canal. All the subperitoneal fat and connective tissue are removed from this region, and the internal oblique is united with mattress sutures to the ligamentum Cooperi and the pectineus muscle in such a manner as to cause its lower margin to be everted.

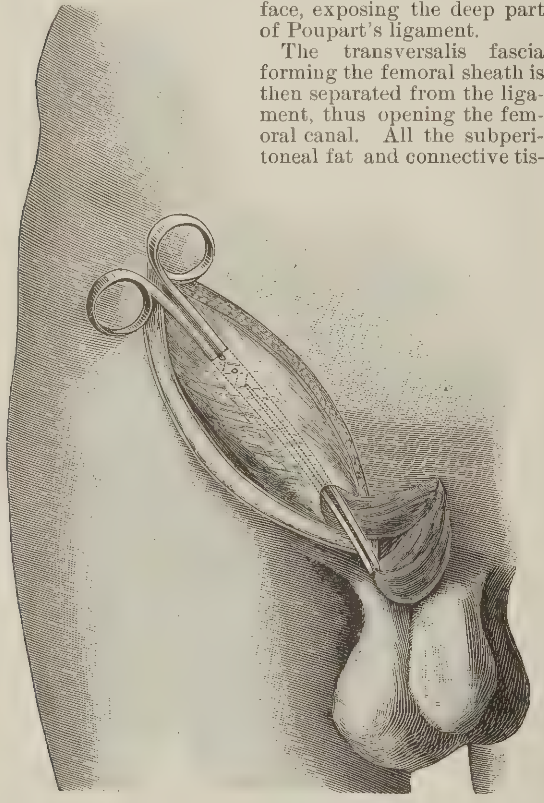

FIG. 2634.—Operation for the Radical Cure of Inguinal Hernia. Kocher's Method. Sac separated and end seized by forceps passed through the transverse incision (*a*) down the inguinal canal. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

The canal is thus closed by muscular tissue. The wound in the external oblique is then sutured and this is followed by closure of the superficial wound.

Results of Operation for Femoral Hernia.—Gordon's operation is so recent that sufficient time for observation has not elapsed and too few cases have been treated to enable one to pass judgment upon it. The far simpler method of Bassini and the purse-string suture have, however, been so efficacious that it seems unnecessary to resort to any other. Bassini reports 54 cases, 41 traced, with no deaths and no relapses. Coley has operated in the same number of cases (by Bassini's and the purse-string methods), most of which have been traced, with no deaths and but one relapse in a Bassini operation in which suppuration occurred.

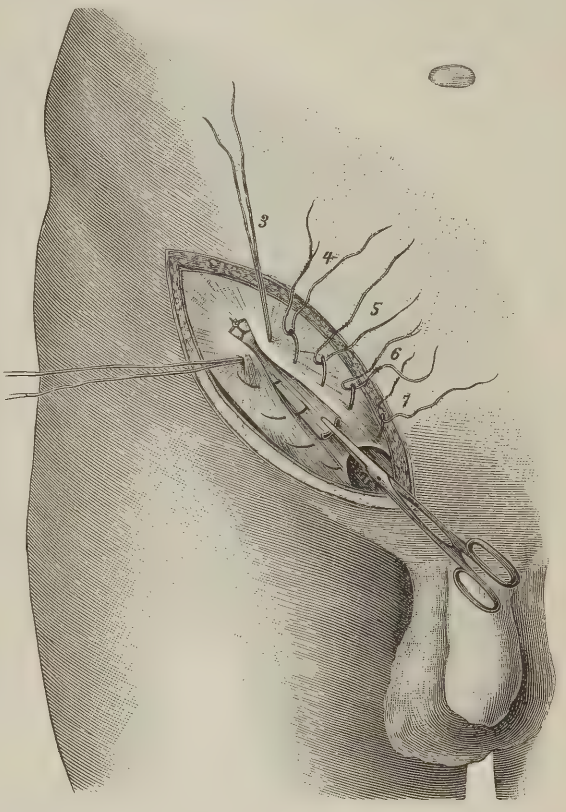

FIG. 2635.—Operation for the Radical Cure of Inguinal Hernia, Kocher's Method. Sac drawn downward on aponeurosis and sewed in place. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

UMBILICAL HERNIA.—Umbilical herniæ are divided into three classes: 1. Congenital umbilical hernia. 2. Infantile umbilical hernia. 3. Adult umbilical hernia.

Congenital Umbilical Hernia or Hernia of the Cord.—This condition is very rare, occurring according to Lin-

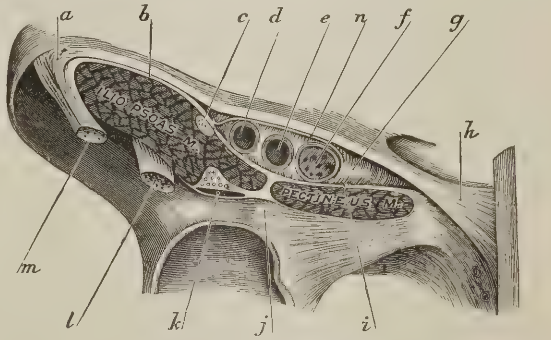

FIG. 2636.—Transverse Section below Poupart's Ligament. *a*, Anterior superior spine of the ilium; *b*, iliac fascia; *c*, anterior crural nerve; *d*, femoral artery; *e*, femoral vein; *f*, septum crurale; *g*, Gimbernat's ligament; *h*, spine of pubis; *i*, pectineal fascia; *j*, ilio-pectineal eminence; *k*, iliac bursa; *l*, rectus femoris muscle; *m*, sartorius muscle; *n*, transversalis fascia. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

fors[21] once in 5,184 cases. In embryos of 10 mm., and that have not reached beyond the tenth week of development, a portion of the intestine is found in the cavity of the umbilical cord which is continuous with the body cavity. After that period the intestine usually recedes into the body cavity proper and the umbilicus is formed by the union of the visceral plates. However, if development of the abdominal wall be arrested, a varying amount of the viscera may be found in the cord at birth. The term congenital umbilical hernia is erroneous, since no umbilicus has been formed.

The wall of the hernia consists of membrane derived from the same layers that form the amnion. The contents may be a varying amount of intestine alone, the liver alone, or the liver, stomach, spleen, and intestine, *i.e.*, complete eventration. In the latter variety the wall nearly always ruptures at birth and death rapidly ensues. In cases in which the contents can be reduced into the abdominal cavity and the cavity closed, operation gives better results than palliative measures. Of 90 cases collected by H. E. Safford,[22] 64 were treated by laparotomy and suture with 65.6 per cent. recoveries; 1 case by simple ligature, with recovery; 3 cases by percutaneous ligature, with 1 recovery; 5 cases by Olshausen's method, with 100 per cent. of recoveries. Of 15 cases treated expectantly, 47 per cent. recovered.

Olshausen's method consists in separation of the skin around the sac, removal of Wharton's jelly, reduction of the hernia *en masse* without opening the sac, and suture of the skin.

Infantile Umbilical Hernia.—This form occurs in infancy and childhood and is due to weakness in the umbilical cicatrix. Berger[23] places the limit between it and adult umbilical hernia at fifteen years. It is about equally common in males and females, the ratio being 1 to 1.6 according to the statistics of the Hospital for the Ruptured and Crippled. According to Berger[23] it forms 22.42 per cent. of all herniæ occurring in male children and 65.34 per cent. of all herniæ in female children under fifteen years of age. This variety is always reducible and is quite amenable to treatment by a simple pad or truss and does not require operation.

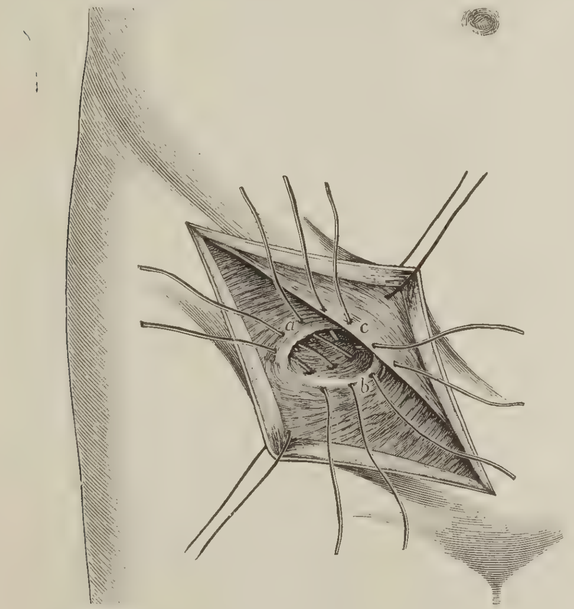

FIG. 2637.—Operation for the Radical Cure of Femoral Hernia, Bassini's Method. *a*, Falciform process; *b*, pubic portion of fascia lata; *c*, Poupart's ligament. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

Adult Umbilical Hernia.—This variety is much more common in females than in males, constituting, according to Berger, 22.16 per cent. of all herniæ in females and 2.5 per cent. of all herniæ in males over fifteen years of age.

Its greatest frequency is during the child-bearing period, and it is the most common of all herniæ in women at the age of forty years.

Two sub-varieties may be recognized, namely, those occurring without diastasis and those accompanied by diastasis of the recti. The first form embraces the greater number of cases occurring in males; the hernia in this case is usually small. The second variety is more common in women, and the tumor may reach an enormous size.

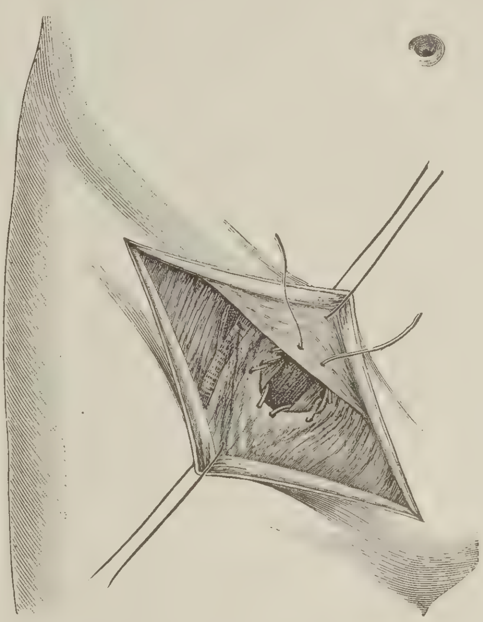

FIG. 2638.—Operation for the Radical Cure of Femoral Hernia. Purse-string suture, Cushing's Method. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

The first form, that occurring without diastasis of the recti, resembles infantile hernia in both symptoms and treatment and rarely requires operation.

Hernia with diastasis is more serious and the symptoms are often most distressing. The hernia is apparently due to the progressive stretching of the abdominal wall from internal pressure or from strains. The umbilicus being the weakest point gives way and the most marked protrusion occurs at this point, although the protrusion may be diffuse and take in a varying amount of the linea alba.

The *coverings* of the sac consist of skin and peritoneum, little or none of the intervening fibrous tissue remaining between them.

The *contents* of the sac consist at first usually only of omentum which soon becomes adherent and irreducible. The transverse colon is found in the sac more commonly than any other part of the intestine.

Symptoms are due to the size of the hernia and to complications, such as adhesions, obstruction, etc. The size of the hernia is an inconvenience and it may ulcerate on account of the poor nutrition of its coverings. It may cause gastric or intestinal symptoms from the inclusion of large amounts of viscera and from the dragging of adhesions. Being commonly associated with loose and pendulous abdominal walls, it is often accompanied by the symptoms of enteroptosis. Pain from adhesions and attacks of local peritonitis are common. Strangulation occurs about as frequently in umbilical as in other herniæ, but the mortality from strangulated umbilical hernia is greater. In gangrenous hernia, according to Gibson,[8] the mortality of umbilical hernia is 67 per cent., of inguinal hernia 26 per cent., and of femoral hernia 37 per cent.

Treatment.—Small reducible umbilical herniæ are best treated by truss. Many of the larger ones can be helped by a well-fitting abdominal support when a pad cannot be worn on account of the irreducibility of the contents.

Many cases of hernia in adults are not suitable for operation inasmuch as this is difficult and often prolonged by adhesions, etc., and because the patients, who are, as a rule, obese women in middle life, bear operations poorly.

In younger women of good fibre, although fat, especially if the protrusion is not too large, operation should be performed, because the hernia tends to increase in size and with the increase in size come the distressing symptoms and complications, and the chance for complete radical cure diminishes. Aside from the risk of operation (the mortality is about 5 per cent. in irreducible cases), the success in regard to permanent cures has not been great. According to Berger,[23] in 30 per cent. of large herniæ and 15 to 20 per cent. of herniæ of moderate size relapse occurs, while in small herniæ the relapses are practically *nil*. In cases in which suppuration occurred, the percentage of relapses was 60.

As would be expected from such poor results, a number of methods of radical cure have been devised. These methods may be classified according to the method of repairing the defect in the abdominal wall. In considering operative methods it must be remembered that in cases of diastasis of the recti the entire abdominal wall becomes thinned and stretched as well as the linea alba, so that the recti muscles may become more than twice their normal width and less than half their normal thickness.

Lineal Approximation of Fascia or Fascia and Muscle (Condamin,[24] Socin, Sanger,[25] Gersuny [26]). After excision of the sac and reduction of its contents, the abdominal wall is sutured layer by layer. In small herniæ the sheaths of the recti may be split and the muscles themselves approximated as well as their sheaths (Socin, Sanger). This method is unsuitable in hernia with diastasis of the recti.

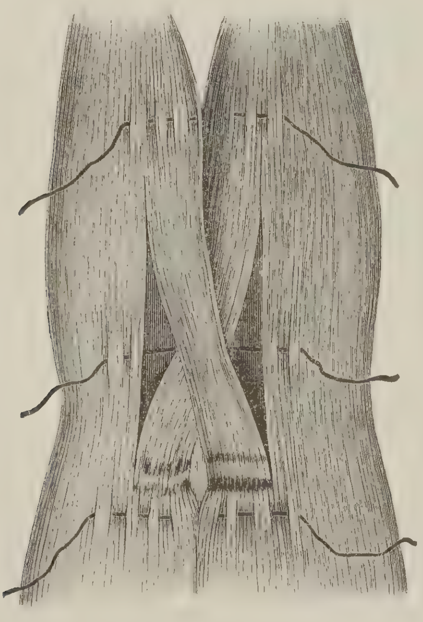

FIG. 2639.—Operation for the Radical Cure of Umbilical Hernia, Dauriac's Method. Muscular segments transferred and united, and sutures laid for closure. (From "Bryant's Surgery." Copyright, 1901, by D. Appleton & Co.)

Interlacing of the Recti (Bacon,[27] Dauriac [28]). In order to fill up the hiatus present after excision of the sac, the inner portions of the recti are split off, and having been cut free at one end are transplanted to the opposite side, thus producing an interchange of portions of the recti following the figure of a cross (Fig. 2639). The chief objection to this method is the impairment of innervation and nutrition in the transplanted muscle.

Involution of Abdominal Wall (Lucas Championnière [29]). The margins of the wound are turned in, thus bringing in apposition the ventral surfaces of the aponeurosis, and retained by means of a series of sutures resembling the Lembert suture. This method is applicable only to cases in which the abdominal walls are very lax.

Flap Operation (Noble,[30] Diakonoff and Starkoff,[31] Heinrich,[32] Hagen,[33] Ferguson [34]). A flap is cut from the ventral sheath of one rectus muscle and is carried across and united to the sheath of the opposite muscle; or a flap is taken from each sheath, the two being joined so as to close the hernial opening. The margins of the flaps may be united or the flaps may be lapped. The flaps are cut so that their attached borders are at the mesal borders of the recti, and when turned in and united their ventral surfaces become dorsal. The chief objection is the lack of nutrition of these flaps.

Lapping of the Abdominal Wall (Mayo,[30] Piccoli,[36] Sapiejko,[37] Blake [38]). This method is particularly adapted to cases with diastasis of the recti and pendulous abdominal walls. It is also suitable to protrusions in the linea alba elsewhere than at the umbilicus.

It consists in the excision of a large elliptical area of skin and fat in either a vertical or a transverse direction, down to and exposing, on one side at least, very completely, the sheaths of the recti. In typical operations done by the writer the incision has included an area from 25 to 40 cm. in length and 15 to 20 cm. in width. The sac is partially or wholly excised and the linea alba is divided for the whole length of the skin incision. The peritoneum is separated if possible from the dorsal surface of one rectus. It is not necessarily opened except at the hernial sac. One musculo-aponeurotic wall is then lapped over the other, as seen in Fig. 2640.

In the writer's cases the amount of lapping has varied from 4 to 10 cm. according to the laxity of the abdominal wall. In one case the greater part of the sac with adherent intestine and omentum was lapped under the opposite rectus. The margin of the underlapping side is sutured to the deep surface of the overlapping side by mattress sutures of chromicized gut which are tied on the superficial surface of the latter. The margin of the overlapping side is tacked with interrupted sutures of the same material to the superficial surface of the underlapping side. The skin wound is then closed without drainage. The results by this method in the hands of the writer and as reported by others have been excellent. Few cases have been under observation, however, for more than two years. Mayo has lapped the walls transversely in some of his cases.

VENTRAL HERNIA.—Ventral hernia is the general term applied to all herniæ of the abdominal wall excepting umbilical and groin herniæ. The herniæ may occur at any part of the abdominal wall. The term therefore includes: (1) Hernia in the linea alba elsewhere than at the umbilicus; (2) diastasis of the recti; (3) hernia in the lineæ semilunares; (4) hernia in the lineæ transversæ; (5) lumbar hernia; (6) traumatic hernia.

Hernia in the Linea Alba.—These herniæ, leaving out umbilical herniæ and those due to diastasis of the recti, occur four times as frequently in males as in females (Macready). They are rare in early life, and most frequent at middle age.

Two varieties occur: 1. Herniæ above the umbilicus—epigastric hernia. 2. Herniæ below the umbilicus.

Epigastric herniæ are usually small and may be multiple and are situated at any point between the xiphoid and umbilicus. They are protrusions through the gaps which are not uncommon between the decussating fibres of the linea alba in this region. They may consist only of properitoneal fat or there may be a well-defined sac with omental or intestinal contents. Symptoms are rarely present. Treatment is indicated when there is impulse or increase in size. They may be retained by truss, but operation is better. The aperture may be closed transversely or vertically.

Herniæ of the linea alba below the umbilicus are often confused with diastasis of the recti. They occur within 5 cm. of the umbilicus, as a rule. They may acquire considerable size. They are best treated by a truss such as is used for umbilical hernia or by operation.

Diastasis of the Recti.—This occurs in childhood and at middle life. In children it occurs as a bulging of the linea alba above the umbilicus, and disappears with the growth of the child.

In adults it occurs practically only in women who have borne children, at or before middle life. It is usually most pronounced below the umbilicus although the whole linea alba suffers. It may be so pronounced that there remains only a thin pendulous bag enclosing a large part of the intestines and sometimes the gravid uterus.

The treatment is by means of an abdominal support. If operation is feasible, that of lapping the abdominal wall (see Umbilical Hernia) will be found peculiarly adapted to these cases.

Hernia in the Lineæ Semilunares.—This is a rare form occurring usually at the level of the semilunar fold of Douglas. About twenty-three cases have been observed. The protruding mass occasionally penetrates only a part of the abdominal wall, resulting in a "masked hernia."

According to some writers direct inguinal herniæ are herniæ of the linea semilunaris, but the writer cannot concur in this, since in these cases the contents of the hernia push forward the transversalis fascia and escape below the insertion of the transversalis and internal oblique muscles.

Hernia in the Lineæ Transversæ.—This is very rare, only seven cases having been oberved at the London Truss Society in sixteen years (Macready).

Lumbar Hernia.—Twenty-six cases of this variety have been collected by Macready, and one has been observed at the Hospital for the Ruptured and Crippled. They occur at or near the tips of the eleventh and twelfth ribs, or at Petit's triangle, between the origin of the latissimus dorsi and that of the external oblique from the crest of the ilium. They occur more frequently in adults than in children and are usually reducible. In six of Macready's cases there was strangulation.

Traumatic Ventral Hernia.—This term includes hernia occurring through scars of accidental or laparotomy wounds. Not infrequently bulgings of the abdominal wall occur at a distance from a wound, which are due to destruction of the innervation of the muscle. Those following laparotomy are more frequent after lateral wounds than after wounds in the median line. They follow most frequently wounds that have healed by granulation, as for instance suppurating appendicitis wounds. Long wounds are more apt to be weak than short ones. The so-called "through-and-through suture" is responsible for many. More careful methods of making and closing abdominal wounds have lessened to a marked degree the frequency of this distressing condition which is a blot upon the page of abdominal surgery.

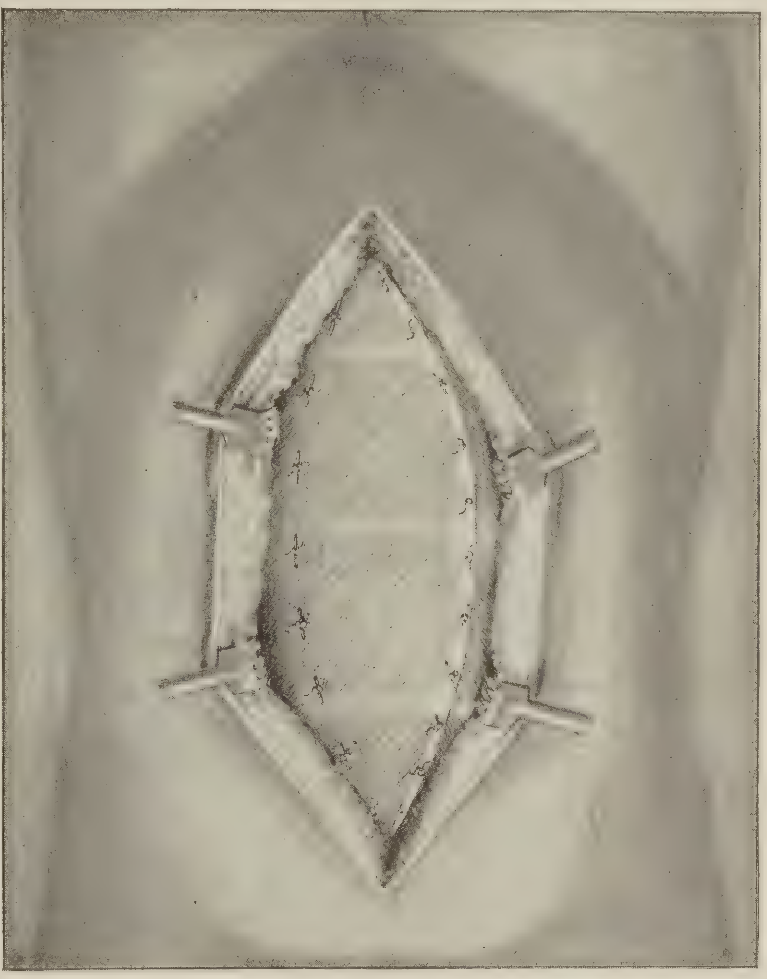

FIG. 2640.—Operation for the Radical Cure of Umbilical Hernia. Method by overlapping of abdominal wall. The right rectus muscle is lapped in front of the left.

The treatment is largely prophylactic and consists in fitting an abdominal support to all weak laparotomy wounds. Most herniæ of this variety are best treated by operation. The muscular and aponeurotic layers should be carefully isolated and separately sutured. The sac may be resected and the peritoneum sutured, or in some cases the peritoneum may not have to be opened. Troublesome adhesions are usually present in those cases in which there has been intra-abdominal drainage for suppurative conditions.

In cases in which the gap was very large, obturators of silver wire netting have been introduced (Phelps[39]).

OBTURATOR HERNIA.—This rare form of hernia passes through the obturator canal, which opens at the mesal and anterior part of the obturator membrane for the passage of the obturator vessels and nerve. The vessels and nerve as a rule lie on the dorso-lateral aspect of the sac.

The protrusion has for its coverings the peritoneum of the upper part of the pelvis or the broad ligament, the subperitoneal fat, and the deep pelvic fascia covering the obturator internus muscle. It may pass beneath the fibres of the obturator externus or take a more superficial course beneath the adductor brevis and pectineus muscles. It is accessible to palpation from the inner aspect of the thigh behind the adductor longus. The contents of the sac are always intestine.

This form of hernia occurs more frequently in women than in men, in the proportion of ninety-three to seven. It occurs in advanced life, the average age being over sixty (Macready).

Symptoms are not as a rule marked until strangulation supervenes. Many herniæ probably become strangulated as soon as protruded. Pain in the course of the obturator nerve has been noticed in forty-two per cent. of the cases. After strangulation tenderness and pain on movement of the thigh become marked. The tumor is not so easily seen as palpated. The neck can often be felt by means of vaginal or rectal examination. The size is usually small, although cases have been seen in which the hernia was the size of an orange.

Treatment.—As mechanical treatment is impossible, all cases should be operated on unless age or disease contraindicates. Most cases are not recognized until strangulation has occurred. The mortality in strangulated cases is high—84.4 per cent. (Macready).

The protrusion can be reached from without by an incision along the border of the adductor longus and between it and the femoral vein. The pectineus and adductor brevis are thus separated, exposing the sac. Or better, especially in strangulated cases, it can be approached by the abdominal route. This allows of better treatment of the intestine, which is important since the average duration of strangulation before operation is long (seven days, according to Macready).

Ischiatic Hernia.—The few instances of this hernia have been imperfectly described. The protrusion escapes at the great sacro-sciatic foramen either above or below the pyriformis muscle. Of seventeen cases collected by Macready the hernia appeared in seven in infancy or at birth. The sexes seem to be equally affected. The contents may consist of intestine, omentum, or some of the pelvic organs as the ovary or bladder. The hernia is usually small, but may extend into the thigh below the glutei or pass over the trochanter toward the groin.

It may be confounded with cysts, abscesses, new growths, or hæmatoma.

Treatment.—The abdominal route or a combined operation would probably be the best way of attacking this variety.

Hernia of the Pelvic Outlet.—This group comprises several varieties in which the abdominal contents escape through the floor of the pelvis. They are much more common in the female. In the male the hernia is into the ischio-rectal fossa or the perineum. In the female it may be into the ischio-rectal fossa, the vagina, or the labium majus. They are named from their superficial location, *ischio-rectal*, *perineal*, *vaginal*, and *pudendal* or *labial herniæ*. Very few have been dissected, so their deep relations are not understood. In some cases the protrusion has occurred at the recto-vesical pouch and in others at the pouch of Douglas. These herniæ are usually small, but may reach enormous proportions containing nearly the whole of the abdominal contents. As a rule they are easy of diagnosis, but a vaginal hernia may be mistaken for a fibroid, polypus, cystocele, or abscess. They seldom become strangulated. Many cases can be treated with a pessary or special truss, although some surgeons advise operation in all cases.

Varieties Depending upon Nature of Contents.—*Vesical Hernia.* The bladder may be protruded through a hernial opening. The condition is four times more common in inguinal than in femoral hernia, and very rare in other varieties of hernia, although it has been observed in ventral and in pelvic herniæ. It is most common in elderly males.

Laxity of the tissues, the pull of the hernia on the peritoneum, and distention of the bladder have been advanced as causes.

Three anatomical varieties are recognized: 1. Extraperitoneal, in which the bladder protrudes alongside of the sac of an ordinary hernia or independent of any sac. 2. Intraperitoneal, in which the bladder appears in the sac covered with peritoneum. 3. Paraperitoneal, in which a portion of bladder only is covered with the peritoneum of the sac. The latter form is the most common.

Of 192 cases collected by Cheesman[40] up to 1901, symptoms were noted in 30. The most constant symptom is the presence of a hernial tumor which disappears on micturition, or pressure upon which causes a desire to urinate or even expels urine from the urethra.

The chief importance of the condition lies in the danger of wounding the bladder in an operation for radical cure. Of the 192 cases quoted, in 47 the bladder was recognized during operation and avoided, and in 93 cases it was wounded, chiefly unintentionally. The presence of the bladder may be suspected if there be an undue amount of fat at the neck of the sac, or if muscle fibres are seen. It may be identified by the passage of a sound in the bladder or by a feeling as of two surfaces rubbing together produced by grasping the mass.

Treatment.—If the bladder is wounded it should be sutured with catgut, preferably in two rows. Catheterization should be frequently performed or a catheter may be left in the urethra for two or three days. The wound should be drained, and if no leakage occurs, the final steps of the radical cure can be completed in a few days. Fifty-five of the ninety-three cases collected by Cheesman were treated by suture, with a mortality of 20 per cent. There was a total mortality of 25 in the 93 cases, but Cheesman attributes the fatal result in 9 cases only to the bladder injury *per se*, a mortality of about 10 per cent.

Hernia of the Large Intestine.—The sigmoid flexure, cæcum, or a portion of the transverse colon may be found in the sac of a hernia.

Especial interest is centred in the cases in which the sigmoid or cæcum is found in the sac of an inguinal or femoral hernia. When the protruded part has a free mesentery the cases do not differ materially from other enteroceles, but in a certain number the bowel is only partially covered with peritoneum, so that a portion of gut is outside of the sac. This condition is known as *slipped* or *sliding hernia ; hernies par glissement* of the French.

According to Coley,[18] sliding herniæ occur as often in children as in adults, although the general belief is that they are more common in middle-aged or elderly males. However, statistics on this point as yet are insufficient. The sliding form is more common in inguinal hernia and when the protrusion is on the right side.

Unless the condition is recognized during the operation the intestine is very liable to be injured. Furthermore reduction is often difficult. The writer has found in his experience that the gut is generally loosely attached to the abdominal wall and can be pushed back *en masse.* Attempts to fashion a peritoneal coat for the bowel should not be made. The redundant sac should be sutured. It will rarely or never be necessary to resect the bowel as has been done by some.

Relapses are more common in these than in other forms of inguinal hernia, for the reasons that the neck of the protrusion is generally very large, and that it cannot be tied off flush with the abdominal wall. Transplantation of the rectus should help in these cases.

Hernia of the Appendix Vermiformis.—The appendix is not uncommonly found in right inguinal or femoral hernia. It may occur alone in the sac, more commonly in femoral hernia. The cases of especial interest are those in which the appendix becomes inflamed (appendicitis in a hernial sac). These cases simulate strangulation and can be differentiated only by the absence of the signs of obstruction. The condition is probably more common than the number of reported cases, sixteen only,[41] would indicate.

Hernia of the Ovary.—On account of error in development the ovary may descend alongside the canal of Nuck into the inguinal canal or even the labium. This condition, *ectopia of the ovary*, is found more commonly in young children, and there is reason to believe that in many cases the organ returns at or before puberty to its normal position. According to Macready,[1] hernia of the ovary occurs in 1.2 per cent. of inguinal herniæ in the female. When there is double ectopia the uterus and tubes are as a rule defective in development, and they may be so in single ectopia. In some cases the tube and even the uterus may be drawn into the sac. Associated with this condition there may or may not be a hernia of the intestine, either congenital into the open canal of Nuck, or into another sac. In most cases the canal of Nuck is open.

In some cases the ovary is reducible and the hernia can then be treated by truss. Other cases should be treated by operation, the ovary being excised or, if its connections can be preserved, returned to the abdomen.

Cases in which the ovary is found with other viscera in otherwise ordinary herniæ are of no particular interest.

Diaphragmatic Hernia.—A protrusion of the abdominal viscera may take place through a wound or through portions of the diaphragm that are deficient. The places where the muscular fibres of the diaphragm are normally deficient are "Larrey's space" between the costal and sternal attachments, and on either side at the lateral portions of the external arched ligaments. A hernia may occur through the œsophageal opening. Finally there may be a congenital defect in the diaphragm. These herniæ are classed as true when the peritoneal sac is present and as false when the viscera lie free in the pleural cavity. The latter form is more common, since the hernia is generally due to trauma.

The protrusion usually occurs on the left side on account of the position of the liver. Varying amounts of the abdominal contents may escape into the thorax. The stomach is the most commonly protruded, although any of the viscera with the exception of the genito-urinary organs may be displaced into the thorax.

The symptoms may be those of pneumothorax, the heart may be displaced, there may be marked interference with respiration, and there may be symptoms of strangulation.

MECHANICAL TREATMENT.—The mechanical treatment of hernia consists in the application of a truss or apparatus to the protrusion. With few exceptions this treatment can be applied only to reducible hernia. Special forms of apparatus have been devised for some forms of irreducible hernia in which operation is contraindicated; such, for instance, is the hinged cup truss for irreducible inguinal hernia.

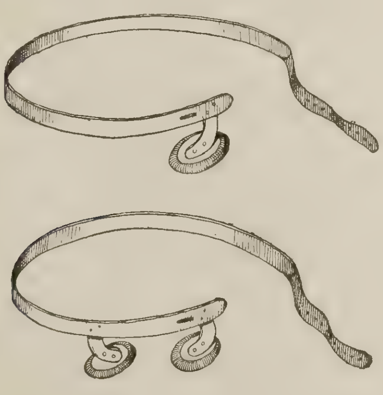

FIG. 2641.—Single and Double Knight Trusses.

For inguinal and femoral hernia three principal varieties of truss are used, namely the "cross body" or Knight truss (Fig. 2641), the frame or Hood truss (Fig. 2642), and the "same side" or French truss.

The chief desiderata in a truss are perfect fit, so that pressure is evenly made on all parts of the pelvis which it comes in contact with; a good spring, the best material being steel, as it combines lightness and durability; and a pad so arranged as to make pressure at the point of exit of the hernia, *i.e.*, over the internal ring in inguinal hernia, and not on the pubic bone.

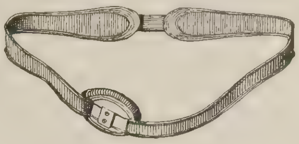

FIG. 2642.—Frame Truss.

The pad is best made of some smooth non-absorbent material as celluloid, hard-rubber, or wood. Sometimes a pad of wood covered with leather is serviceable.

When the pressure of a hard pad is unbearable, as it sometimes is in large herniæ, the elastic water pad can be used.

In adults trusses may be removed at night, as a cure is rarely attainable, but in children, in whom the descent of the hernia would preclude all chance for a cure, the truss should be worn day and night.

It is impossible in so brief an article to give the indications for the use of different trusses, and the methods of application. These points are largely learned by practical experience.

For umbilical hernia special forms of truss have been devised, but for most cases the best apparatus is a well-fitting abdominal support with a pad of suitable size to control the protrusion and of a thickness equal to that of the subcutaneous fat.

For umbilical hernia in children a broad strap of zinc oxide rubber plaster with a wooden button over the hernia makes a very efficient apparatus.

Results of Mechanical Treatment.—*Inguinal Hernia.* According to Coley by far the greater majority of cures are obtained in the first year of life. The best results are obtained with the spring truss in infancy, it being far superior to the "worsted" or "skein" truss.

In children cures are more often obtained in girls than in boys, the reverse being true in adults. About two-thirds of the cases of inguinal hernia can be cured in childhood. Cures are seldom attained in patients over twenty years of age.

Femoral Hernia is practically incurable by mechanical means.

Umbilical Hernia. In the infantile form a cure is nearly always obtained. In adults the most that can be hoped for is limitation of the size of the protrusion.

Joseph A. Blake.

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HEROIN, diacetyl-morphine [$C_{17}H_{17}.(CH_3CO)_2.NO_3$], is one of the group of morphine compounds to which belong codeine, dionin, and peronin. It occurs as an odorless and slightly bitter, white, crystalline powder, insoluble in water, and soluble in dilute acids. The hydrochloride, the salt generally used, is freely soluble in water and alcohol, insoluble in ether, and incompatible with alkalies.

Experiments show that heroin is not absorbed by the unbroken skin, and has but slight effect on mucous membranes. It tends to cause dryness of the throat and slight irritation of the gastro-intestinal tract as manifested by nausea, vomiting, and diarrhœa. These effects are, however, uncommon. In therapeutic doses the circulation is unaffected, though heart failure may follow a large dose. The main action of the drug is upon the respiratory organs, as it tends to diminish bronchial secretion, while it slows and increases the depth and strength of respiration. Dreser demonstrated that a smaller amount of oxygen was used by the system and less carbon dioxide eliminated; in other words, that metabolic processes were retarded. On account of this diminished tissue-activity there is a slight temporary lowering of body-temperature. In very few cases has any hypnotic or analgesic effect been noted. Heroin is a very powerful remedy, the maximum dose being one-twentieth that of codeine. Observers agree that the dose of 0.01 gm. (gr. $\frac{1}{6}$) should not be exceeded. Though not very common, cases with unpleasant sequelæ are met with by every user of the drug. Therapeutic doses have been followed by dryness and irritation of the pharynx, nausea, vomiting, constipation, diarrhœa, languor, and, rarely, excitement or delirium. A case of the writer's always became greatly excited after a dose of morphine or heroin, but never after codeine. Some writers advise adding potassium iodide to prevent dryness of the throat, and cascara or calomel for the constipation. A dose of 0.015 gm (gr. $\frac{1}{4}$) given by mistake to an asthmatic patient was followed by prostration, cyanosis, amaurosis, restlessness, pulse of 40, feeble heart action, spasm of the legs, persistent nausea, subnormal temperature, and a semi-comatose condition.

Among the large number of published reports most authorities agree that heroin is valuable in the treatment of bronchitis, bronchial asthma, pulmonary tuberculosis, and whooping-cough, while opinions differ as to its efficacy in neuralgia, angina pectoris, cardiac dyspnœa, etc. The writer used it in over one hundred cases of tuberculosis, and found it of distinct use, but inferior to codeine in allaying the cough, irritability, and pain, and in promoting sleep. Heroin had little, if any, effect on the pain, dyspnœa, or night sweats. Loewenthal employs it in infantile diarrhœa and colic, the maximum dose for a child of one month being 0.0002 gm. (gr. $\frac{1}{300}$), of six months 0.00027 gm. (gr. $\frac{1}{220}$), and of five years 0.0024 gm. (gr. $\frac{1}{25}$). Heroin has not proven of any special value in diabetes, and so far as known does not create a drug habit. Indeed it is recommended as a substitute for morphine on the withdrawal of the latter drug for morphinism.

W. A. Bastedo.

HERPES.—The term herpes (from ἕρπειν, to creep), formerly employed to designate a large number of diseases of the skin of varying etiology, is restricted at the present time to a class of affections whose distinguishing clinical feature is a grouped vesicular eruption seated upon an inflamed and slightly swollen base. If the term is used in this restricted sense there are practically but two varieties of the disease, viz., simple herpes, of which there are a number of regional forms which differ but little from one another in their clinical characters; and herpes zoster, which clinically and etiologically is quite distinct from the first-named variety. The herpes iris of some authors properly belongs to erythema multiforme; herpes gestationis is one of the forms of the dermatitis herpetiformis of Duhring; while the herpes circinatus and herpes tonsurans of some continental authors are parasitic affections, much more frequently characterized by erythematous and squamous eruptions than by vesicular lesions.

The appearance of the herpetic eruption is preceded for a variable period, usually short, by a sensation of burning, pricking, or slight itching; after a few hours an erythematous, slightly swollen patch appears upon which small papules arise which are speedily transformed into a group of vesicles with clear serous contents, each group containing from three or four to a dozen or more lesions. The vesicles, at first discrete, later become more or less confluent through increase in size, often forming small blebs. After from twenty-four to forty-eight hours the contents of the vesicles become cloudy, then purulent, and yellow or brown crusts form, which after a week or ten days fall off, leaving a slightly reddened patch which lasts but a few days and disappears without leaving any trace of its existence.

Herpes Simplex.—In the great majority of cases the eruption of simple herpes is situated upon the face, usually the lower half; hence it is also spoken of as facial herpes. The parts of the face most frequently attacked are, in the order of frequency, the lips, the lower oftener than the upper lip, the cheeks, and the alæ of the nose. It sometimes occurs upon the external ear and still less frequently upon other parts of the cutaneous surface. It usually begins quite abruptly with a sensation of heat or itching; the skin over a limited area becomes red and slightly swollen, and upon this area a group of small papules appear which in a short time become clear vesicles. The vesicles, discrete in the beginning, enlarge slightly for a short time after their appearance and frequently coalesce, forming blebs that vary in size from that of a pea to that of a dime; but when the lesions are very small and few in number, they usually remain discrete. At the end of a day or two the contents of the vesicles become purulent; they then dry up, forming yellow or brown crusts, which fall off in a few days more, leaving slightly red, or occasionally transiently pigmented stains, the entire attack lasting from four or five days to two weeks.

The eruption is not always limited to the skin, but may appear upon the adjoining mucous membranes, even the larynx in rare instances being invaded. When the eruption occurs upon mucous surfaces it presents marked differences from that upon the skin. Owing to the moisture with which the affected parts are constantly bathed, the vesicles appear as white opaque elevations which are soon transformed into shallow erosions through spontaneous rupture. Herpes of the mucous membranes is, in the great majority of cases, associated with similar lesions upon the skin, although pharyngeal herpes may occur alone; the mucous membranes attacked being usually those of the lips, the cheeks, and the pharynx.

In a considerable proportion of cases the appearance of the eruption is preceded or accompanied by sensations of chilliness and some elevation of temperature; hence the popular terms "cold sore," "fever blister," applied to these eruptions.

In many individuals there is a marked tendency to recurrences, and this continues for years, the eruption appearing with the slightest derangement of the general health, or following slight irritations of the skin.

Although, as a rule, there are usually but two or three groups of vesicles, and often but one, each containing a moderate number of lesions, it happens in rare instances that the eruption is much more extensive, covering, it may be, almost the entire cutaneous surface. Such extensive cases have been most frequently reported by French observers, Rendu having only recently described a case of generalized herpes produced by the ingestion of uncooked shell-fish. It seems to me, however, that such eruptions are very closely allied to, if not actually examples of, bullous erythema multiforme, rather than true herpes.

Facial herpes frequently occurs in febrile diseases of various kinds, such as pneumonia, in which it is quite common, in typhoid fever, in the malarial fevers, and in cerebro-spinal meningitis, a favorable prognostic significance being attributed to it. In the malarial fevers it may occur with each febrile paroxysm, or in exceptional cases it may replace it, as has been noted by several writers.

Under the name herpetic fever, various authors have from time to time described an endemic affection in which, after marked constitutional disturbances, such as chills and elevation of temperature, an herpetic eruption appears upon the face or other parts of the cutaneous surface. A remarkable endemic of this kind has been reported by Savage in which, in an institution for boys, thirty-nine cases of herpes occurred. In this outbreak the eruption was preceded by chills, nausea, and elevation of temperature varying from 102° to 104.5° F., and was accompanied by sore throat and swollen glands, the attack lasting four days.

Herpes Genitalis.—The genital organs of both sexes are frequently the seat of herpes, the eruption occurring, in men, upon the margin of the prepuce or upon its inner mucous surface (herpes præputialis, herpes progenitalis), upon the glans, and, much less frequently, upon the skin of the shaft of the penis; in women the parts affected are the vulva, the mucous surfaces of the labia majora, the labia minora, the clitoris and the prepuce, and the mucous membrane about the meatus urinarius. The appearance of the eruption is preceded by more or less burning or stinging, which is shortly followed by redness, œdema, and the formation of groups of vesicles which are usually quite small. When the skin surfaces are attacked the vesicles after a day or two dry up into brownish crusts which fall at the end of a week, leaving a slightly reddened, or, it may be, pigmented patch. When the eruption occurs upon the mucous surfaces, as the inner side of the prepuce, the glans, or the labia minora, the vesicles rupture almost immediately, forming shallow erosions, the bottoms of which are often covered with a whitish or gray membrane. Occasionally the eruption appears in successive crops separated by intervals of some hours or a day or two, thus prolonging the attack greatly. Fournier has observed a case in which the disease was thus prolonged for five weeks; but this is altogether exceptional. When the affected parts are irritated by violence or by the application of caustics, as not infrequently happens, the inflammation may be considerable and may be attended by marked induration of the base of the vesicles; this induration being especially apt to occur upon the glans in the region of the sulcus. In such cases the glands in the groin may be noticeably swollen. In rare cases the eruption occurs upon the urethral mucous membrane, giving rise to ardor urinæ and, in the male, to a serous discharge. Although, as a rule, subjective symptoms are limited to slight burning or itching, it occasionally happens that the pain is severe, even neuralgic in character.

In women the eruption is sometimes quite extensive, covering the cutaneous surface of the vulva, and the labia majora and minora with numerous groups of vesicles and erosions, and at times extending down upon the inner surface of the thighs. The pain and burning in such cases are severe, and with the marked swelling which is commonly present walking is difficult and at times impossible. Superficial ulceration may occur with the formation of vegetations, producing an appearance much like that of a syphilitic mucous patch; indeed, according to Fournier, it is sometimes impossible to make a positive differential diagnosis until after the lapse of a considerable period of time.

Of all the forms of herpes the genital is most apt to recur, the interval between the attacks varying from a few weeks to several months. In a considerable proportion of cases each coitus in the male and each menstrual period in the female is followed by an attack, the recurrences continuing for years. On the other hand there may be but a single attack.

Simple herpes is in many cases, no doubt, a local manifestation of a general toxæmia. Its frequent association with such general diseases as pneumonia, typhoid and the malarial fevers, epidemic cerebro-spinal meningitis, and other maladies of an infectious nature, lends strong support to such a view of its etiology. In a considerable proportion of cases, however, it must be regarded as due to local conditions associated with a special predisposition. In genital herpes excessive irritations and congestions, physiological or pathological, such as coitus and the menstrual period, play important rôles in the production of the affection. Uncleanliness and previous venereal disease are potent etiological factors. As Unna and Fournier have pointed out, prostitutes are especially liable to suffer from herpes of the genitalia.

The herpetic eruption is the result of a peripheral neuritis of an acute transitory character, the consequence of a direct or reflex irritation of the terminal nerve branches distributed to the skin. Unna, who had the opportunity to examine lesions from three cases of genital herpes, found a fibrinous inflammation of the epidermis, the primary changes affecting the more superficial prickle cells. The entire epidermis was lifted from the papillary layer of the corium, forming a blister whose walls and contents had undergone coagulation necrosis. Beneath the vesicle the entire cutis was œdematous and the blood and lymph vessels were markedly dilated. A striking histopathological difference between the vesicle of simple herpes and that of herpes zoster is the absence of the so-called "ballooning" of the epithelial cells in the former.

The *diagnosis* of simple herpes is usually made without the slightest difficulty. The purely vesicular character of the lesions, the grouped arrangement of the eruption, its localization upon the face, in most cases about the mouth, or upon the genitalia, and the acute course of the disease are features so characteristic that there is little chance for error. When, however, the eruption is seated upon the mucous membranes, particularly those of the genitalia, the erosions which follow the vesicles may be mistaken for venereal ulcers or the initial lesion of syphilis. The herpetic lesion is superficial and does not tend to extend like the chancroid; it exudes an abundance of serum instead of pus, which, as Leloir has pointed out, may be much increased by squeezing the lesion between the thumb and finger; its borders are apt to present a festooned or polycyclic outline; and lastly, there are often groups of well-defined vesicles in the neighborhood. It is to be distinguished from the initial lesion of syphilis by its brief duration and the absence of the peculiar induration characteristic of the chancre. It should not be forgotten, however, that the herpetic lesion, under the influence of irritants, may present an indurated base much like that seen in the chancre, and that in such cases there may be swelling of the inguinal glands. Fournier has called attention to the fact that the chancre may be preceded by herpes; and it is always wise, in view of the very serious results which may follow an error in diagnosis, to be very guarded in expressing an opinion in doubtful cases until sufficient time has elapsed to make the diagnosis certain.

In the *treatment* of simple herpes all irritant applications should be avoided. Frequent applications of ninety-five-per-cent. alcohol in the early stages of the eruption will sometimes partially abort it. If there is marked burning, a saturated aqueous solution of boric acid will be found very useful in relieving this symptom; or a solution of resorcin, from eight to ten grains to the ounce of water, may be even more effective. A lotion containing twenty grains each of sulphate of zinc and sulphide of potassium, as recommended by Duhring, is also a useful remedy.

In genital herpes the parts should be kept scrupulously clean, and nothing better for this purpose can be used than a saturated solution of boric acid, which should be freely and frequently mopped upon the affected parts. When the mucous surfaces are the seat of the eruption, they should be kept apart by pieces of gauze wet with the boric acid solution; or, after careful cleansing, they may be covered with a dusting powder of talc and oxide of zinc, to which, if there is annoying pain, from ten to twenty per cent. of acetanilid may be added, or the acetanilid may be used alone. The resorcin lotion above referred to will often be found a very soothing and cleansing application. Lotio nigra may be employed in many cases with good results. If suppuration occurs, weak solutions of bichloride of mercury should be applied several times a day, but this remedy must be used cautiously as it sometimes proves irritating. As a preventive measure, circumcision has been recommended in recurrent herpes genitalis; it is, however, an uncertain remedy. Arsenic given internally for a considerable period exercises a decided influence in preventing recurrences in many cases, and should always be tried when other remedies have failed. *Milton B. Hartzell.*

HERPES ZOSTER.—Herpes zoster, also known as zona, zoster, shingles,—this last probably being a corruption of the Latin *cingulum*,—names all having reference to the girdle-like arrangement which the eruption often exhibits, usually begins with pain, commonly of a neuralgic character, varying in degree from mere discomfort and soreness to the severest neuralgia, and situated in the regions presently to be the seat of the herpetic eruption. Exceptionally in the beginning of the attack there is some elevation of temperature with slight malaise. After a prodromal period, varying from a few hours to several days, groups of papules seated upon a reddened and slightly swollen base appear in the painful areas, and in the course of a few hours they become vesicles with transparent contents. With the appearance of the eruption the pain may diminish, but there are frequent exceptions to this rule. The vesicles, for the most part discrete, tense, and showing no tendency to spontaneous rupture, vary in size from a hemp seed to a large pea, and are arranged in variously-sized groups from one or two to a dozen or more in number, separated by areas of normal skin, and situated over the distribution of some nerve usually at points where branches are given off to the skin. The several groups of vesicles do not appear simultaneously, but new ones continue to form for some days, the last-formed groups often containing many papules which do not develop into vesicles, and imperfectly developed vesicles. After a day or two the vesicular contents become turbid, then purulent, and later brown or black crusts form which fall off at the end of from ten days to two weeks, leaving transiently hyperæmic patches, or slight pigmentation, and frequently permanent scars. The duration of the entire attack is from ten days to three weeks; but when the inflammation is unusually severe, or when complications, such as suppuration and gangrene, occur, it may last much longer.

The amount of pain present varies within wide limits. In children and young adults it is often entirely absent, or so slight as to cause little or no complaint; but in elderly subjects it is commonly severe, often demanding large doses of powerful narcotics for its relief, and sometimes continuing for weeks or even months and years.

In an overwhelming majority of the cases the eruption is limited to one side of the body, although it is not at all uncommon to see a group of vesicles extend some distance beyond the middle line. While it may occur over the course of any peripheral nerve, it is much more frequently situated upon the trunk than upon the extremities In one hundred cases in which the location of the eruption was specially noted by Crocker, it was observed to occur upon the trunk fifty-four times.

Variations from the ordinary type of zoster occur in a small proportion of cases. The vesicles may be filled with blood instead of serum, giving the eruption a blue or black appearance. In this variety, known as *zoster hæmorrhagicus*, the pain is as a rule extremely severe, and ulceration more or less deep is prone to occur.

In cases of unusual severity suppuration may take place, and in rare instances gangrene of the skin occurs, either after the appearance of the vesicles or before these have had time to develop. As the result of the severe and at times deep-seated inflammation, extensive and indelible scarring follows, which later may become the seat of keloid.

As *zoster gangrenosus hystericus* Kaposi has described an atypical form of zoster that occurs in hysterical women. This variety of the malady is characterized by repeated attacks separated by intervals of a few weeks or some months, the eruption being unilateral or bilateral. Gangrene of the skin at the base of the vesicles occurs, and keloid-like cicatrices follow. This disease is certainly closely related to, if not identical with, the multiple hysterical gangrene of the skin of other authors; and while it is mentioned here, I think it is doubtful if it properly belongs to herpes zoster.

While almost invariably limited to one side of the body, the eruption may be bilateral. According to Hyde, bilateral zoster is most apt to be seen in those suffering from syphilis or in those taking arsenic.

Colombini has reported a case in which the eruption was universal, groups of vesicles occurring over the branches of all the cutaneous nerves. The disease in this instance was most likely of malarial origin, as the patient had had repeated attacks of malarial fever, and the eruption appeared shortly after one of them.

Second attacks of zoster are rare, although not so infrequent as formerly supposed. In recurrent zoster the same region may be affected several times, or new regions may be invaded with each new attack. Recurrences are most likely to be observed in those cases in which the disease is of traumatic origin; as in one under my observation some years ago in which the sciatic nerve was injured by a fracture of the femur. In this case there were many attacks preceded and accompanied by severe pain, most of them in the region of the distribution of the sciatic nerve and its branches. While the pain usually diminishes with the appearance of the eruption and ceases entirely with its complete involution, it may persist for a considerable period, especially in elderly subjects, after all other evidences of the disease have disappeared. Other sequelæ are local paralyses, and various disturbances of sensation, either alone or associated with trophic changes.

The principal local varieties of herpes zoster, named according to the region in which the eruption is situated, are Z. capillitii, Z. frontalis, Z. facialis, Z. ophthalmicus, Z. colli, Z. brachialis, Z. pectoralis, Z. abdominalis, Z. femoralis. In these several local varieties the disease presents practically the same clinical features, particularly so far as the eruption is concerned, but it may vary considerably as to extent and the severity of the inflammation and pain which accompany it.

In Z. frontalis the eruption follows the distribution of the supraorbital branch of the fifth pair, extending over the lid, one-half the forehead, and up into the scalp. This form is sometimes followed by marked scarring resembling the pits produced by variola.

In Z. ophthalmicus, in which the branches of the fifth pair distributed to the eye are affected, the pain is often of the severest character, and the various structures of the eye may be inflamed, the inflammation being in rare cases so severe as to cause destruction of this organ. Fatal meningitis has been known to result in this variety of zoster.

In Z. facialis the second branch of the fifth pair is concerned, the eruption occurring on the cheek, the side of the nose, and one-half of the upper lip. In exceptional cases it also occurs upon the mucous membranes of the cheek and pharynx. Loss of the teeth and necrosis of the jaw have been noted as rare complications.

The supraspinous portion of the scapula and the upper arm are the regions affected in Z. brachialis. The forearm and the fingers are not often involved. This is usually a mild form of the malady.

Z. pectoralis is the variety oftenest seen, and the one from which the disease gets its various names signifying a girdle. Groups of vesicles extend from the spine forward to the sternum. In many cases the eruption consists of but two or three groups, one close to the spine, a second in the axillary line, and a third, often composed of imperfectly developed lesions, near the anterior middle line. In severe cases the groups of vesicles may coalesce, forming a continuous half-girdle. In this variety of zoster the pain which sometimes precedes the appearance of the eruption may be mistaken for a pleurisy.

In Z. femoralis the eruption is situated upon the anterior surface of the thighs, the external genitalia, and upon the buttocks. The legs and feet are only rarely attacked.

Etiology.—Zoster occurs much more frequently in the young than in the old, but old age is by no means exempt. In three-fourths of the cases observed by Crocker the patients were under twenty years of age. Although infrequent in infancy cases have been reported in infants from four days to several months old. The sexes appear to be equally liable. Cold, damp, and other climatic influences seem to play some part in its production since it occurs most frequently in winter and spring.

It sometimes occurs in connection with such diseases as influenza, malaria, and tuberculosis. Winfield has reported a number of cases in which the presence of the plasmodium malariæ was demonstrated; and it has been observed often enough in the subjects of tuberculosis to suggest the possibility of a causal relationship between the two maladies.

As was first pointed out by Hutchinson, and afterward confirmed by other observers, arsenic when given in large quantities for a prolonged period may produce zoster by setting up a neuritis. Other toxic substances, such as carbonic oxide gas, have also produced the disease. In a considerable number of instances the eruption has been observed to follow injuries to nerves. Occasionally it seems to be of reflex origin, as is shown by a case reported by Jewel in which a crural zoster resulted from disease of the uterus; and in other cases it has seemed to be due to irritation in the alimentary canal caused by the presence of tapeworm. Lastly, it is very probable that in a considerable proportion of cases it is the result of a specific infection, although the infectious agent is as yet unknown. Its occurrence in epidemics, its undoubted occasional contagiousness, its self-limited course, and the rarity of second attacks are features of the malady which are strongly in favor of such a view. From the foregoing brief summary it is evident that there is no one cause of herpes zoster, but that it may be produced by any agent capable of setting up a neuritis.

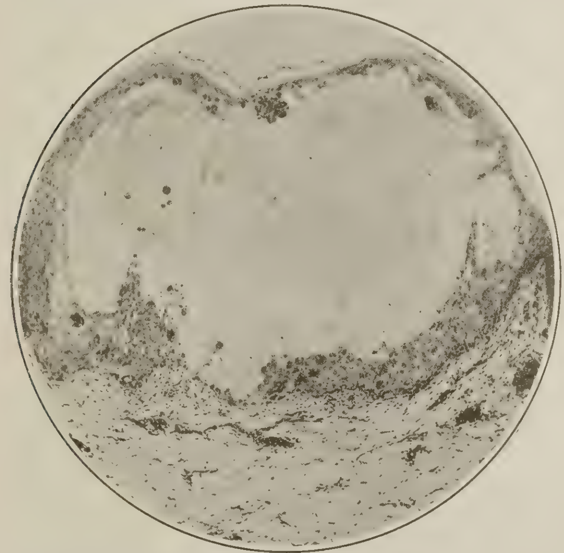

FIG. 2643.—Vesicle of Zoster. Upon the bottom of the vesicle are numerous cells which have undergone alteration like that shown in Fig. 2644. (Author's own case.)

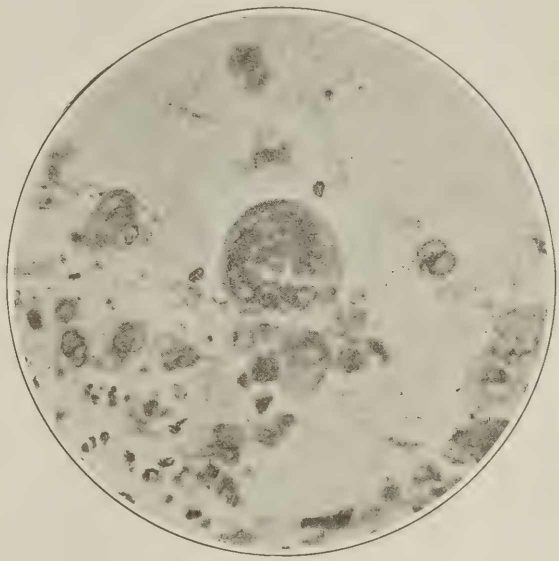

FIG. 2644. — Epithelial Degeneration; Large Protozoön-like Cell. (From author's own case of herpes zoster.)

Pathology and Pathological Anatomy.—Proof of the neuritic character of the disease was first furnished by Baerensprung, who found that there was inflammation of the ganglia and the nerves distributed to the area occupied by the eruption. The ganglia do not always share in the inflammatory process, as Baerensprung supposed, but the inflammation is sometimes limited to the peripheral parts of the nerve. The pathological alteration of the nerve is not always of an inflammatory character, but may be the result of hemorrhage, the pressure of new growths, or traumatism.

The zoster vesicle lies deeply within the epidermis, the bottom being formed by the papillary layer of the corium upon which lie masses of altered epithelium. The most striking feature is the peculiar alteration which many of the epithelial cells have undergone, by which they have been transformed into bodies resembling more or less closely protozoa. These bodies were regarded by Pfeiffer, who was one of the first to describe them, as parasites, and were believed by him to be the cause of the disease; but the later investigations of Unna, Torok, myself, and others have clearly demonstrated their epithelial character. These altered cells are often enormous in size, round, oval, or balloon-shaped, with a double-contoured wall or capsule within which are from two to a dozen or more large round and oval nuclei which often present a peculiar beaded limiting membrane. The cavity of the vesicle contains a few free epithelial cells, a small number of leucocytes, and fibrin. The papillæ and that part of the corium immediately beneath the papillary layer are abundantly infiltrated with leucocytes, and there is dilatation of the blood-vessels.

Diagnosis.—The clinical features of zoster are, in the great majority of cases, so well defined that the diagnosis is usually easily made. The two diseases with which it is most likely to be confounded are vesicular eczema and simple herpes.

It may be distinguished from eczema by the grouping of the vesicles over the course of known nerves, by the accompanying neuralgia, by the absence of itching and discharge, and by the vesicles, unlike those of eczema, showing no tendency to spontaneous rupture.

It differs from simple herpes by its unilateral distribution, by the pain which precedes and accompanies the eruption, and by the infrequency of second attacks. Simple herpes is most apt to occur about the mouth and upon the genitalia, regions seldom invaded by zoster.

Prognosis.—The prognosis is in most case favorable, the disease usually terminating in from ten days to three weeks. In severe attacks, however, or when ulceration, deep-seated inflammation, or gangrene occurs, the duration may be greatly prolonged beyond the usual period. In elderly subjects, less frequently in the young, persistent neuralgia of a severe type may follow, lasting for months or years. In exceptionally severe cases of ophthalmic zoster disfiguring, scarring, loss of an eye, and even death may result.

Treatment.—In mild cases of herpes zoster only the simplest treatment is required. The vesicles should be protected from the friction of the clothing by covering them with two or three thicknesses of gauze or a thin layer of absorbent cotton, having first freely applied a simple dusting powder, such as equal parts of starch and oxide of zinc, to which, if there is burning or pain, camphor or morphine may be added. Internal remedies administered with the view of aborting or controlling the eruption are of more than doubtful efficacy. Phosphide of zinc, in doses of from one-sixth to one-third of a grain given every three hours, is recommended by Thompson and Bulkley for the relief of the pain and the control of the eruption, but other observers have not found it reliable. In cases in which the pain is severe, antipyrin, phenacetin, or acetanilid may be given in doses of from five to eight grains every three or four hours; when these fail to afford relief morphine, given hypodermatically, may be employed. Locally frequent application of ninety-five-per-cent. alcohol is often very useful; or, instead of simple alcohol, alcoholic solutions of resorcin fifteen grains to the ounce, or a solution of carbolic acid five to ten grains to the ounce, or of menthol ten grains to the ounce, may be used. Such lotions should be mopped on gently every three or four hours with a soft cloth, care being taken not to rupture the vesicles. Duhring specially recommends a lotion containing from twenty to sixty grains each of sulphate of zinc and sulphide of potassium to the ounce of water; he finds it very useful in relieving pain and drying up the eruption. Collodion, either alone or with one or two grains of morphine to the ounce added, may be painted over the eruption for the purpose of favoring its absorption and alleviating the pain. For the relief of persistent neuralgia, galvanism is perhaps the most useful remedy, mild currents being more useful than strong ones. Crocker finds repeated blistering over the root of the affected nerve very efficacious in some cases. An abundance of easily digested, nutritious food, and cod-liver oil are also indicated.

Milton B. Hartzell.

HESPERIDIN. See *Citrus.*

HETOCRESOL; HETOFORM; HETOL.—*Hetocresol* or cinnamyl-meta-cresol, *Hetoform* or bismuth cinnamate, and *Hetol* or sodium cinnamate are remedies introduced for the treatment of tuberculosis. *W. A. Bastedo.*

HEXAMETHYLENE-TETRAMINE. See *Urotropin.*

HIGHLAND SPRINGS.—Lake County, California.

Post-Office.—Highland Springs. Hotel and cottages. These excellent springs are found within the edge of the mountains, about four miles from Kelseyville and seven miles from Lakeport. They are reached by the Southern Pacific Railroad, on the south to Calistoga, and thence by stage; also by the Northern Pacific road on the southwest to Cloverdale, and thence by stage. The drive from Calistoga or Cloverdale is exceedingly picturesque. The road leads through a romantic mountain region until an elevation of 3,200 feet is gained. Here a grand panorama is revealed. As far as the eye can reach in every direction are mountains and valleys, peaks upon peaks, mountain streams and brooks, forest and shrubbery. The most picturesque of all is the view northward over Clear Lake and Lake County. This is a magnificent sheet of water twenty-five miles long and six to eight miles wide. It has an elevation of 1,200 feet above the Pacific Ocean, and lies peacefully smiling in the embrace of the mountains on every side, with the towering head of "Uncle Sam" above them all. The bright, cultivated fields appear like a checker-board in the valley below. The gigantic oaks, the largest in the State, are scattered here and there to lend variety to the enchanting picture. The descent to the springs is made in much less than half the time it takes to make the ascent, and the resort is soon seen lying in a level sequestered spot surrounded by hills and by trees of many years' growth. At Highland we find a commodious hotel and many elegant cottages built with a view to health and pleasure combined. A large, pure mountain stream which is well supplied with fish runs past the hotel. The usual mild, genial climate of Lake County prevails here. The altitude is about 1,700 feet, and it is claimed to be an excellent place for consumptives. There are about twenty springs at Highland, five of the most important having been examined by Anderson in 1888. These analyses show results practically identical with those of Professor Rising in 1882, except in the case of the "Neptune" spring, which seems to have lost greatly, especially in calcium salt, in the course of six years. The principal springs are the "Magic," the "Neptune," the "Seltzer," the "Dutch" or "Ems," and the "Diana" spring. The waters are chiefly of the alkaline-saline type, most of them containing a well-marked proportion of iron. Following are the analyses of two of the representative springs:

THE SELTZER SPRING.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	0.67
Sodium carbonate	2.06
Sodium bicarbonate	12.72
Potassium bicarbonate	.50
Magnesium bicarbonate	33.95
Calcium bicarbonate	52.25
Manganese bicarbonate	Trace.
Ferrous carbonate	1.43
Silica	5.13
Alumina	1.75
Organic matter	Trace.
Total	110.46

Free carbonic acid gas, 98.41 grains.
Temperature of water, 60.4° F.

The water is antacid, laxative, and diuretic, and has been used with much satisfaction in dyspepsia, neuralgia, kidney and bladder troubles, calculi, etc., and in rheumatism, gout, and skin diseases.

THE "DUTCH" OR "EMS" SPRINGS.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	1.76
Sodium bicarbonate	17.50
Sodium carbonate	2.45
Potassium bicarbonate	.78
Magnesium bicarbonate	66.55
Magnesium carbonate	1.63
Calcium bicarbonate	57.32
Manganese bicarbonate	Trace.
Ferrous carbonate	1.53
Silica	7.22
Alumina	.12
Organic matter	Trace.
Total	156.86

Free carbonic acid gas, 58.90 grains.
Temperature of water 77° F.

This water is more diuretic and laxative than the Seltzer. The Highland bathing water is artificially heated.

It is also an alkaline-saline fluid with considerable carbonic acid gas and some iron. The baths are used for rheumatism and joint affections. *James K. Crook.*

HIGHLAND SPRINGS.—Androscoggin County, Maine. Post-Office.—Lewiston. Cottages.

Highland Spring is located in Highland Park, comprising over sixty acres of elevated and wooded land, about two miles from Lewiston station. The spot offers exceptional advantages to persons wishing to camp during the summer. The waters of this spring have enjoyed a considerable reputation for a long time past. They are bottled and sold extensively for table purposes. The following analysis was made by Richard C. Stanley, Ph.D., State assayer of Maine:

One United States Gallon Contains:

Solids.	Grains.
Iron carbonate	1.10
Iron oxide	.31
Potassium and sodium carbonate	.83
Magnesium carbonate	1.23
Potassium and sodium sulphate	.31
Sodium chloride	1.00
Total	4.78

This is an excellent, palatable water and possesses the properties of a mild ferruginous tonic.

James K. Crook.

HIP-JOINT.—The development of the pelvic limbs into organs for support and propulsion has given to the joints by which they are articulated with the trunk a peculiar character of strength and solidity. While movement is free in every direction, and the femur can be circumducted as well as rotated, yet these movements are much less extensive than at the shoulder. The head of the distal bone is more completely enclosed, and the capsular ligament is stronger and narrower at its distal insertion, so as to offer a resistance to luxations. Besides this, certain modifications have been caused by the strain and pressure occasioned by the erect position. It would naturally be supposed that in a ball-and-socket joint the surfaces of contact would be perfectly spherical, and, indeed, the head of the femur is usually described as presenting from two-thirds to three-fourths of the surface of a sphere fitting closely the acetabular cavity. Aeby[1] and Schmid[2] have, however, shown that this is not quite correct, as there is a slight flattening of the surfaces and a thickening of their encrusting cartilages where they are subjected to the greatest pressure. This is more marked in the adult.

The liability of the articulation to disease and injury is considerable, both on account of its size and of the pressure upon the surfaces. It is therefore important to determine its precise position and relations—and this is by no means easy, as it lies buried under thick masses of muscle. In front is the reflected tendon of the ilio-psoas, a bursa (*B. subiliaca*), which sometimes communicates with the joint cavity, intervening. Above, the reflected tendon of the rectus femoris and the gluteus minimus are firmly united with the capsule (see Fig. 2645). Internally lies the pectineus above, also united with the capsule, and the obturator externus below. The tendon of this latter muscle also lies posteriorly, together with the obturator internus, the gemelli, the pyriformis, and the quadratus femoris.

All these form an immediate investment for the joint, and are themselves partially covered by a second mass composed of the tensor vaginæ femoris, the gluteus maximus and medius behind and externally, the biceps group behind, and the adductor group internally.

Over these muscles there stretches the fascia belonging to the different groups, and in several situations this notably strengthens the joint capsule, especially where the iliac fascia comes down from the ilio-psoas, where the pectineal fascia passes outward upon the capsule from the pectineus, and, externally, where a strong process passes inward between the tensor vaginæ femoris and the rectus femoris.

The depth at which the articulation lies makes it difficult to obtain any positive knowledge as to the condition of the joint by direct manipulation, but a fairly accurate notion of its situation may be had by noting the surface forms and bony points of the region. As to the bones, note first the anterior superior spine of the ilium, always marked even in the fattest subjects; then the spine of the pubis, which can easily be found by abducting the thigh and then running the finger along the strong tendon of the adductor longus which starts up. Joining these two points is Poupart's ligament, which may easily be felt. The muscular prominence on the outer side of the leg is caused by the tensor vaginæ femoris, on the inner by the abductor muscles, and the triangular interval between, which reminds one distantly of the axillary space, is the *fossa subinguinalis*, or Scarpa's triangle. It is through the middle of this that the great vessels pass down the thigh, and the beating of the femoral artery, which lies nearest the joint, may be felt by pressing just below Poupart's ligament. The joint is about half an inch external to this, and in a very lean person (easier in cadaver) the head of the femur may be felt rolling under the fingers by pressing deeply here while an assistant extends and rotates the limb. This is impossible, however, when the subject is even moderately fat. A fulness and tenderness here are noted in the early stages of hip dis-

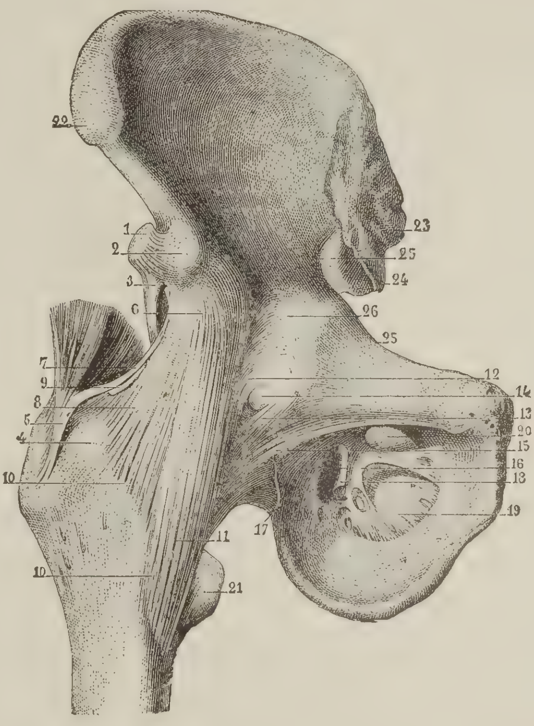

Fig. 2645.—Front View of the Hip-Joint. (From Sappey.) 1, Tendon of rectus femoris, cut; 2, its attachment to the antero-inferior iliac spine; 3, reflected portion of the tendon; 4, tubercle of the trochanter major; 5, tendon of the gluteus minimus; 6, the attachment of the ilio-femoral ligaments to the antero-inferior iliac spine; 7, fibrous union of the capsule with the tendon of the gluteus minimus; 8, superior ilio-femoral ligament; 9, section of a very thin fibrous lamella which covers over and crosses the ligament obliquely; 10, 10, thinner portion of the capsule between the two ilio-femoral bands; 11, anterior ilio-femoral ligament; 12, 13, thin portion of the capsule arising from the ilio-pectineal eminence, and from the horizontal ramus; 14, orifice in the capsule communicating with the bursa beneath the tendon of the ilio-psoas; 15, pubo-femoral ligament; 16, 17, 18, 19, fibrous bands relating to the obturator membrane; 20, the obturator foramen or subpubic canal; 21, lesser trochanter; 22, antero-superior iliac spine; 23, postero-superior iliac spine; 24, postero-inferior iliac spine; 25, ilio-pectineal line; 26, ilio-pectineal eminence.

ease, when there is effusion into the joint. Pus forming around the joint is always confined, and burrows extensively along the lines of fascia above mentioned. An abscess pointing below Poupart's ligament, and external to the vessels, usually comes from the joint.

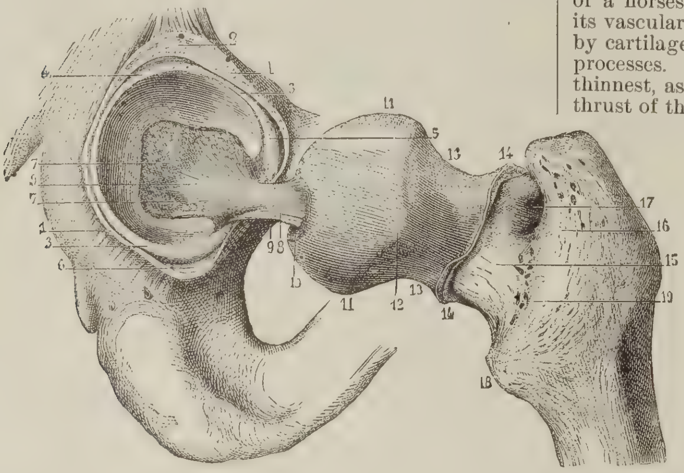

FIG. 2646.—The Hip-Joint Opened. (From Sappey.) 1, 1, Transverse section of the capsular ligament, showing its variations in thickness; 2, section at the situation where it is strengthened by the ilio-femoral bands; 3, 3, free edge of the cotyloid ligament; 4, 5, 6, semilunar interspaces which separate that ligament from the capsule; 7, 7, pad of fat at the bottom of the acetabulum; 8, 9, the ligamentum teres; 10, the umbo, or depression on the head of the femur; 11, 11, head of the femur; 12, farthest extent of the articular surface behind; 13, 13, that portion of the neck behind that is invested with synovial membrane; 14, 14, oblique line where the synovial membrane is reflected; 15, that portion of the neck behind that remains without the capsule: 16, great trochanter; 17, digital fossa; 18, lesser trochanter; 19, posterior intertrochanteric line.

Two other bony points should be noted. First, the tuberosity of the ischium, which is the part upon which the weight of the body rests in sitting. In the erect posture it is concealed by the gluteal fold behind, but may readily be made out by palpation. Second, the great trochanter, which is situated on the outer part of the upper thigh, about four inches below and behind the anterior superior iliac spine. The top of it is on a level with the pubic spine, and about three-fourths of an inch below the head of the femur. When the leg is abducted the trochanter will be found at the bottom of a depression; when adducted and rotated inward it makes a prominence. The anterior superior iliac spine, the tuberosity of the ischium, and the pubic spine are all about equally distant from the bottom of the acetabulum. A line connecting the first two is known as Nélaton's line. It grazes the great trochanter and passes directly over the middle of the acetabulum when the thigh is slightly flexed. By noting the extent of displacement of the trochanter with reference to this line, much can be made out as to dislocation or fracture. Upon rotating the femur the trochanter will be seen to describe the arc of a circle, with a radius equal to the length of the head and neck; in case of fracture the arc is much less, the bone rotating merely upon the axis of the shaft. The patient being in the recumbent position, a fracture of the neck may also be detected by noting the displacement of the trochanter toward a line dropped vertically from the anterior superior spine of the ilium (Bryant).

Of the articular surfaces the acetabulum is the more liable to disease, because it is composed of a greater variety of elements. The three primitive bones, the ilium, ischium, and pubis, which unite to make the innominate bone, all participate in the formation of the cavity. Up to the age of puberty the component bones are separated by a Y-shaped strip of cartilage. It is probably on account of the unusual activity required by the osteogenic process here that the joint is so prone to disease in childhood, hip disease rarely occurring after ossification is completed. The primitive divisions of the cavity are still indicated in the adult by notches on the edge of the acetabulum. The lower part of the cavity is not covered with cartilage, but offers a rough depression filled in with fat and processes from the synovial membrane, in which vessels pass to supply the joint (Haversian gland) (Fig. 2646). It results from this that the part of the joint covered with cartilage has somewhat of a horseshoe shape. The lower part, both because of its vascularity and on account of its want of protection by cartilage, is usually the first attacked by inflammatory processes. It is also in this situation that the walls are thinnest, as it is necessary to buttress above against the thrust of the femur in the erect position. The thinness here explains the ease with which inflammatory processes may be propagated, an arthritis giving rise to a pelvic cellulitis, and a pelvic abscess occasioning inflammation of the joint. Perforation of the acetabulum is not very common, as the pressure is but slight.

Within the pelvic cavity the situation corresponding to the acetabulum is covered in part by the obturator internus. When the perforation occurs it must therefore be in one of three positions—either upon the muscle, behind it, or in front of it. In the first instance the pus passes out with the tendon of the muscle at the lesser sciatic notch, and points upon the nates. When the perforation occurs behind, the pus goes into the ischio-rectal fossa, and discharges through the perineum or into the rectum. When it occurs in front, the pus passes upward along the sheath of the obturator vessels and makes its appearance in the groin.[3]

The acetabular cavity is not quite an inch in diameter and does not comprise an entire hemisphere. This deficiency is made up by fitting to the rim an elastic structure of fibro-cartilage called the cotyloid ligament. This is triangular on section and spans over the notch at the bottom of the cavity, being there known as the transverse ligament. The cavity thus deepened, is somewhat more than a hemisphere. The cotyloid ligament is applied closely to the surface of the femur, and helps to retain it in position—acting, however, as a valve, as it is easily stretched sufficiently to disarticulate the bones. Both the head and the neck of the femur should be regarded as taking part in the articulation, the first by actual contact, the second by its inclusion in the capsule. The articulating surface of the head has been estimated at nine and a half square inches, and when to this is added the surface of the acetabulum and capsule, there are about twenty square inches of synovial surface subject to inflammation.[3] It is not, therefore, surprising that

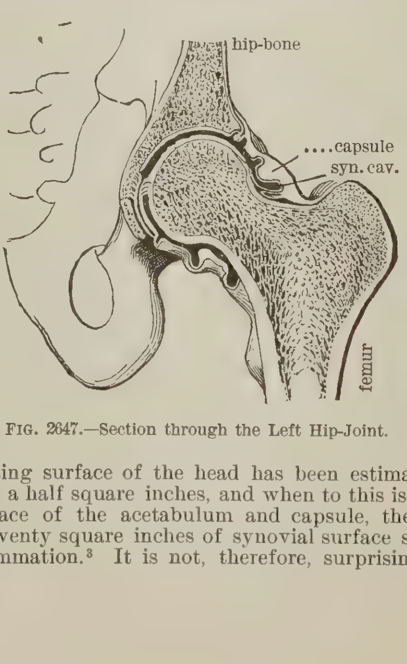

FIG. 2647.—Section through the Left Hip-Joint.

the joint should be susceptible to injury. The cartilaginous covering extends farther from front to back than from side to side, indicating the direction of the greatest excursion of the articular surface. A short distance below the summit of the head, and a little nearer the posterior than the anterior surface, there is a slight depression, termed the umbo, for the insertion of the ligamentum teres (see Figs. 2646 and 2647). The neck is obliquely set upon the shaft at an angle which varies according to the age of the individual, but not so much as is generally supposed, being about an average of 131° for the child and adult, and 128° for the aged.[4] Individual variations are more pronounced, lying between 121° and 144°, or more. The angle is less in females than in males. These facts explain the greater frequency in women and aged people of fracture from shocks delivered upon the neck in a vertical direction, as the nearer the angle between the neck and the shaft is to a right angle the greater would be the shearing stress under such circumstances. The compact tissue is mainly at the lower part, where the most bracing is required. Caries, therefore, works much more rapidly upon the upper surface.[3]

An apparatus connected with the synovial membrane of the joint is the so-called ligamentum teres, or round ligament—which is not round, nor, properly speaking, a ligament, being a flattened band quite similar to the synovial processes with which it is united at both ends (see Fig. 2646). It passes from the fossa at the bottom of the acetabulum to the umbo upon the head of the femur. It does not, like interosseous ligaments, extend in the shortest direction from one bone to the other, but is in a manner rolled around the lower part of the head (Fig. 2647). It is composed of loose connective tissue and contains vessels.

Various surmises have been made as to its use. It was formerly held to be for the purpose of limiting outward rotation and adduction during flexion [5], [6], [7]. It has been shown, however, that if the capsule is left intact, these motions are more closely limited than when it is severed, and the strain comes alone upon the ligamentum teres. Tillaux[4] thinks that it tends to break shocks delivered by the femur upon the top of the acetabular cavity in jumping, etc. Sappey[8] supposes that its principal function is the protection and conveyance of vessels to nourish the head of the femur; but Hyrtl[9] finds that, upon careful injection of the arteries, only the round ligament and the fatty cushion at the bottom of the acetabulum become reddened, and that at the insertion of the round ligament upon the femoral head the capillary arteries loop back and unite with veins. An injection of the superior nutrient artery, on the contrary, fills the capillaries of the cancellous tissue of the head. This explains the well-known pathological fact that an intracapsular fracture of the femoral neck is likely to be followed by non-union of the fragments, notwithstanding that the ligamentum teres may be left intact. Langer,[10] however, finds that, in young subjects, vessels of considerable size pass through directly into the proximal epiphysis of the femur, and suggests that its function is connected with the nourishment of that epiphysis. When this becomes united, its vascular system is connected with that of the nutrient artery, and the branches received through the ligament gradually atrophy, until in old age they are almost entirely wanting.

Welcker[11] has made a careful examination of this ligament in the animal series, as well as in human embryos, and considers it a process of synovial membrane originating as a fold at the side of the articular surface, and gradually detached by the twisting of the limbs. In some animals quite near man, as the orang (occasionally also in man), it is wanting, but it may be said to be generally present when there is much differentiation of the hind limbs. In the tapir it is reduced to a process attached only at the side, a condition occasionally found in the human shoulder-joint.

One of the most interesting views as to the nature of this puzzling structure is that of Sutton,[12] who thinks it a vestige of a tendon, probably a former attachment of the pectineus. The ambiens muscle of ostriches, homologous with the pectineus, carries its tendon into the joint to the head of the femur. In the lizard *Sphenodon*, the pectineus has two heads, one going to the femur, the other to the pubic bone, reminding one of the biceps brachialis. In the horse the ligamentum teres has two parts, one of which is continuous with the pectineus.

The capsule of the joint is much stronger and thicker than that at the shoulder, and confines the bones more closely. It is united above just beyond the base of the outer edge of the cotyloid ligament, and to the transverse ligament. Upon the femur it passes considerably beyond the articular surface, taking in a portion of the neck. In front it reaches to the anterior intertrochanteric line, while behind, because of the numerous muscles coming to be inserted into the trochanter, it does not reach the posterior line, but covers only about the inner two-thirds of the neck. It follows from this that all fractures of the neck are intracapsular in front, that they are intracapsular in front and behind when situated at the internal half, but when at the external half they may be intracapsular in front and extracapsular behind. Tillaux[4] notes that the synovial membrane is reflected within the capsule somewhat in advance of the fibres of the capsule, and shows that a fracture might be intracapsular and still not involve the synovial membrane. He therefore proposes that the fractures of the neck be divided into intra- and extra-articular.

The innermost layer of the capsule, not including the synovial membrane, is a thin layer of circular fibres. These become more apparent behind and at the lower part, where they are known as the zona orbicularis. This is the weakest part of the capsule, and, consequently, the point where pus usually bursts through, and where spontaneous dislocation takes place in hip disease. A blow on the great trochanter forcing the head of the bone downward and backward is apt to occasion dislocation, especially when the thigh is flexed so as to make the head of the femur press against this weak part. The circular fibres are not confined to this spot, but are found intermingling with others in all parts of the capsule. They undoubtedly exercise a restraining influence against dislocation of the bone by constricting the capsule at its femoral insertion.

In those situations where special stress occurs, longitudinal bundles of considerable strength have been formed upon the surface of the capsule. These form four tolerably distinct bands. Two of these are caused by the necessity of supporting the trunk in the erect position. They pass from the anterior inferior spine of the ilium downward, diverging from each other like the branches of an inverted **Y** (**⅄**), one going to the base of the trochanter major, the other to just above the trochanter minor. They have usually been described collectively as the ilio-femoral ligament, ligament of Bertin, or **Y** ligament of Bigelow. Welcker[11] has, however, suggested that, as the two bands are distinct and perform different physiological functions, they should receive separate names, and proposes to call them the superior and anterior ilio-femoral ligaments. They are both exceedingly strong. It is because of this that, in the barbarous punishment of "drawing" a criminal, by means of four horses attached to his limbs and proceeding in opposite directions, the separation at the hip-joint had usually to be completed with a knife, the ligaments resisting after several hours of trial—as was the case at the execution of Ravaillac, the assassin of Henry IV., and of Damiens, who attempted the life of Louis XV.

The superior ligament is perhaps the strongest ligament in the body, being from one-fourth to one-half an inch thick (7 to 14 mm. Welcker), and stronger than the tendo Achillis. Its action is to limit the extension of the femur upon the pelvis. In the erect position the weight of the body falls behind the hip, and the pelvis is accordingly tilted backward, putting this band on the stretch, and it then sustains the whole weight of the trunk, head, and arms, a great economy of muscular force being thus effected. It also limits outward rotation and adduction.

The anterior ligament is also very strong, being nearly one-fourth of an inch thick (4 to 5 mm.), and the longest strengthening band of the capsule. It assists the superior ligament in limiting extension, but not in the same plane, the plane of limitation for the superior ligament being nearly parallel to the axis of the femoral neck, that of the anterior with the axis of the shaft.

The two ligaments are but slightly developed before the erect position is attained. Indications of them are found early, but they increase with the growth. In animals that can stand partially erect, such as apes and some marsupials (kangaroo), the ligaments are strong; in others slight.[13]

They have an important influence in determining the deformity which results from dislocations of the femur, and may be used as a fulcrum in reducing them.[14] Thus, it is the superior ligament which holds the neck fixed, and hence causes the inward turning of the toes in dislocation backward. In thyroid dislocation the anterior ligament causes in a similar way an eversion of the toes.

Another strengthening band of the capsule is the pubofemoral ligament, which stretches from the pectineal eminence of the pubic bone to the lesser trochanter. It is from 2 to 3 mm. thick, and limits abduction. The ischio-femoral band is of about the same size, and stretches in a similar way from the tuberosity of the ischium to the digital fossa of the great trochanter, along the line of the tendon of the obturator internus, with which it is somewhat blended. It limits rotation inward. It is sometimes described as ending upon the capsule, and therefore called ischio-capsular (Henle); but Welcker and others find the arrangement described the usual one.

The action of these four bands is such that in passing from the flexed to the extended position they wind around the neck in such a way as to shorten the capsule, which, being closely united with the zona orbicularis, is drawn up against the edge of the acetabular cavity and surrounds the lower part of the head as with a ring. It may be said that the contraction is such that dislocation is impossible in the extended position.

The brothers Weber made the discovery that the head of the femur is held in position by atmospheric pressure, the amount of weight thus lifted being somewhat greater than that of the limb. This greatly economizes the muscular force required for walking. The closely fitting cotyloid ligament assists this greatly, and dislocation is very unusual, if not entirely impossible, without injury to it. Men and animals that ascend mountains to a height where the air becomes sufficiently rarefied to be of less effect in upholding the weight of the limbs suffer from weakness in the joints. Hyrtl[9] states also that mountaineers, who have trained their muscles by long use in a rarefied atmosphere, are somewhat inexpert in the use of their legs when they descend to the valleys.

The arterial supply to the joint is, as has been stated, through the notch in the lower part of the acetabulum, some collateral circulation being imperfectly effected by means of capillary branches from the nutrient artery of the femur. The capsular ligament is remarkable for the number of vessels and nerves which ramify in it.

The joint is usually said to be supplied with nerves from the sciatic and from the obturator trunks, but recently the nervous supply has been carefully reinvestigated by Chandelux, who finds it to be as follows: In front, a twig from the musculo-cutaneous branch of the anterior crural is given off a short distance from the point where the nerve is lost in the pectineus. This passes behind the sheath of the femoral vessels, and reaches the capsule at its antero-internal portion. It supplies the internal half of the anterior part of the capsule Behind there is a branch of somewhat variable origin, but always emanating either directly or indirectly from the sacral plexus. It descends upon the posterior part of the articulation, reaches the capsule behind and above, and is distributed to the internal half of the posterior portion. No nerve was found from the obturator trunk.

It is believed that this distribution explains certain phenomena connected with coxalgia. In certain forms the propulsion of the head against the acetabular cavity by percussion upon the knee is hardly felt, although a direct pressure upon the internal part of the femoral head in front is very painful, as are also forced movements of outward rotation. In this case it is supposed that there is a coxalgia of capsular origin.

Again, the characteristic attitude is also explained. Often adduction of the leg is accompanied by inward rotation, but in some patients outward rotation occurs. As the anterior articular nerve is only a bifurcation of the branch going to supply the pectineus, it may easily be imagined that a neuritis, arising perhaps from the synovial membrane, affects the pectineal branch and causes the muscle to act.

The pain in the knee, which is an almost constant symptom in hip disease, has usually been considered to be caused by the reflex action through the articular branch from the obturator nerve. It may, however, be caused by a neuritis extending to the internal saphenous nerve, or, as is more likely, by the pressure which the effusion into the joint makes upon the obturator nerve where it lies upon the anterior part of the capsule.[8]

Frank Baker.

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HIP-JOINT, CONGENITAL DISLOCATION OF THE.—Congenital dislocation of the hip-joint, or perhaps more properly misplacement, is by far the most common and the most important of this class of disability.

It is much more common in females than in males, as is illustrated by the following statistics: In 671 cases collected from different sources by Lorenz 589 (87.8 per cent.) were in females and 82 (12.2 per cent.) in males. Of 1,039 cases seen at the Polyclinic in Milan, 867 (83.4 per cent.) were in females, 172 (16.6 per cent.) in males. In 500 cases recorded at the Hospital for Ruptured and Crippled, 413 (82.6 per cent.) were in females and 87 (17.47 per cent.) in males.

The dislocation is more often unilateral than bilateral. In Lorenz's series of 671 cases, 421 (64.4 per cent.) were single; 225 of the right, 196 of the left side. In 245 cases (36.6 per cent.) the displacement was bilateral. In the statistics of the Hospital for Ruptured and Crippled 353 (71.3 per cent.) were unilateral; 135 of the right and 218 of the left side; 136 (27.87 per cent.) were bilateral.

The dislocation at the time when the patients are brought for treatment is usually posterior, upon the dorsum of the ilium. In other instances it is anterior, the head of the bone lying below the anterior superior spine. Occasionally the displacement appears to be a subluxation due to laxity of the capsule; in such cases it may be directly upward, supracotyloid. This form is more often seen in infancy, and it represents possibly the primary displacement of a much larger proportion of the total number, which changes to the ordinary form under functional use.

Pathology.—The degree of abnormality of the joint and of the surrounding parts varies with the age of the patient and with the strain and friction to which the displaced parts have been subjected. At birth it may be assumed that the head of the bone lies in close proximity to a somewhat rudimentary actetabulum. At a later time, when the joint is exposed at operation at the age of four years or more, the rudimentary acetabulum may be partly filled with cartilage, fat, and fibrous tissue. As a rule, however, a well-marked ridge indicating its posterior and upper margin can be made out and in many instances it appears to be of fair size and depth, but always misshaped to a greater or less degree, smaller and shallower than normal, and in older subjects contracted at its upper margin to a somewhat triangular form.

The capsule is elongated to accommodate the upward dislocation of the femur. It is hypertrophied, especially where it covers the upper part of the head of the bone, and it is often drawn into a shape like an hourglass; the upper part contains the head of the bone; the anterior wall is drawn tightly across the acetabulum, forming at its upper border a narrow, slit-like communication, through which the ligamentum teres passes, if it be present. The interior of the capsule is in part lined with synovial membrane, and it often contains more synovial fluid than is found in the normal joint.

The ligamentum teres, although probably present at birth in a large proportion of the cases, becomes attenuated and ribbon-like with the increasing elongation of the capsule, and after the age of five years it is usually absent or very rudimentary.

A shallow depression formed in part by the direct pressure of the head of the bone through the adherent capsule, and in part the result of irritation of the periosteum is usually found upon the ilium, but as it is not often of sufficient depth to assure a secure support for the head of the femur its upper margin gradually recedes or two distinct depressions may be formed one above the other. The upper extremity of the femur is usually somewhat atrophied. The neck is often shorter than normal, its angle may be lessened and in many instances its forward inclination is increased (anteversion). The head of the bone may be nearly normal, although usually it is somewhat flattened on its inner and under surface, or it may be somewhat conical, or again compressed from side to side to an almond shape or otherwise distorted.

There are also secondary changes in the bones of the pelvis. In unilateral dislocation the pelvis is usually somewhat atrophied on the affected side, and a lateral inclination of the spine may be present. The final changes in the pelvis caused by the bilateral dislocation are more important; its inclination is increased, the lumbar lordosis is exaggerated, the sacrum is forced forward and downward so that the antero-posterior diameter is lessened; the tuberosities of the ischia are everted and the transverse diameter of the pelvic outlet is increased.

The long muscles of the thigh are shortened, while those attached about the trochanter are changed in direction and are usually lengthened. There is also a slight general muscular atrophy that is particularly marked on the gluteal group. The changes become more marked with increasing age, and in some of the adult specimens but little resemblance to the normal parts remains.

As a rule, congenital dislocation of the hip is not accompanied by defective development or deformity elsewhere; although cases are sometimes seen in which a general laxity of ligaments is present or in which the dislocation may be one of a series of deformities and malformations.

Etiology.—Nothing positive is known of the etiology of the dislocation. In a small proportion of the unilateral cases it may be due to violence at birth, but the fact that nearly eighty-five per cent. of the patients are females indicates that the primary cause can be neither injury nor disease.

Hereditary influence can be established in a few instances and the displacement may be present in more than one of the same family. The writer has examined three female children, in a family of nine, in each of whom there was dislocation of the left hip, the order being the third, eighth, and ninth child; also twins, one having single and the other double dislocation. In but two instances in a large number of observations, was it certain that congenital displacement was present in the mothers of the patients.

Of the various theories that have been advanced to account for the condition, the most reasonable seems to be defective development either of the entire acetabulum or of its posterior margin. This defective development may be primary or it may be secondary to a fixed position of the limb in adduction and flexion.

Heusner has endeavored to explain the greater liability of females to the dislocation by disproportionate laxity of the capsule which he thinks is characteristic of the sex. It is probable that the dislocation in many instances is at birth a subluxation only and becomes complete through muscular action and by the use of the limb in standing and walking.

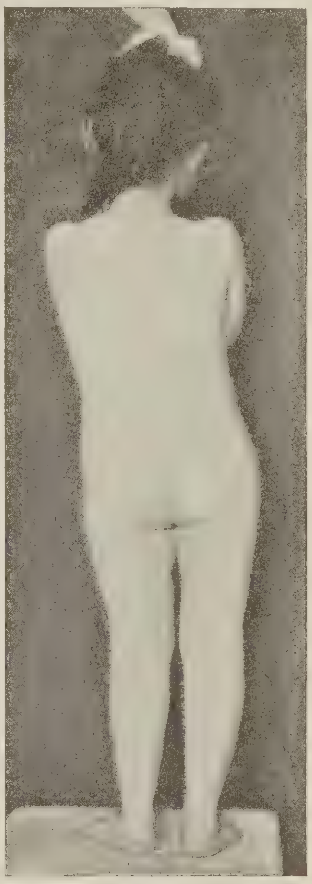

Fig. 2648.—Unilateral Dislocation Showing the Inclination of the Body Toward the Shorter Limb.

Symptoms.—The displacement does not as a rule attract attention until the child begins to walk; although in some cases the mother may have noticed a peculiar breadth of pelvis, or a "lump" on the buttock, or a "snapping" about the hip-joint, or a peculiar attitude of the limb before this time.

Unilateral Dislocation.—If the displacement is of one side, a limp is immediately apparent, and this becomes more noticeable as the child grows older. The limp is characteristic of the affection, for the limb is not only shorter than its fellow but owing to the elasticity of the capsule it becomes still shorter when weight falls upon it. Thus in walking there is a peculiar lunge of the body toward the affected side. In most instances the dislocation is upon the dorsum of the ilium, the head of the femur being displaced upward and backward. In compensation the pelvis is tilted toward the short leg and its inclination is increased. It is also rotated forward so that the anterior superior spine lies on a lower plane, and in advance of that of the opposite side.

When the child begins to walk the shortening of the limb is from one-half to three-quarters of an inch. In adolescence it is from one and a half to three inches or even more, the shortening increasing as the capsule elongates under pressure.

Other signs are the flattening of the buttock and the elevated and prominent trochanter which may be seen or felt as an abnormal lateral projection, on a level with the anterior superior spine, which is, as has been stated, somewhat tilted downward.

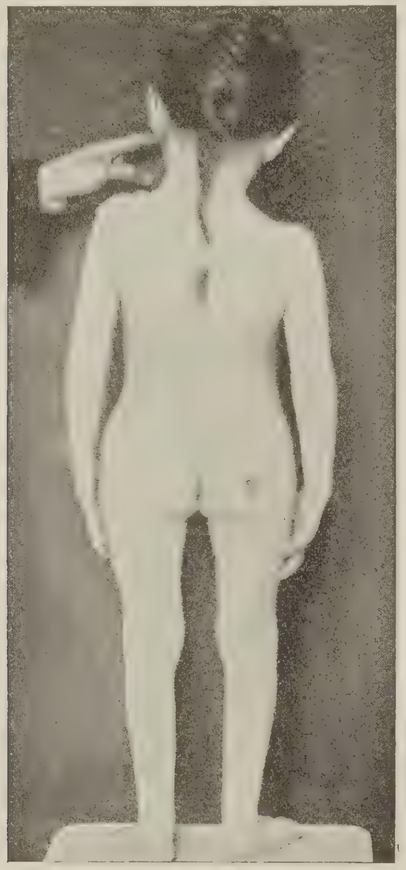

FIG. 2649.—Bilateral Dislocation Showing the Relative Shortening of the Lower Limbs and the Apparent Broadening of the Pelvis.

In childhood the attitude of the limb is practically normal and motion is unrestricted. There is, in fact, an abnormal mobility that may be demonstrated by alternate traction and upward pressure on the limb. As the femur becomes larger and the upward displacement increases, the mobility is restricted; the range of abduction in particular is much diminished and not infrequently the limb becomes permanently adducted and flexed, thus adding the apparent shortening of adduction to that caused by the dislocation.

Bilateral Dislocation.—When the dislocation is bilateral the shortening of the limbs is, as a rule, equal or nearly so, and as both femora are displaced backward the pelvis is tilted forward. In compensation the hollow of the back is increased, the abdomen protrudes, the buttocks are flattened, the pelvis appears to be abnormally wide, and the thighs are separated by a considerable interval. The limp characteristic of the single displacement is replaced by an exaggerated waddle, a "sailor gait."

In early childhood there may be no symptoms other than the physical signs that have been described, but as the child becomes more active it usually complains of discomfort after exertion. It is easily fatigued and at times it may suffer actual pain. These symptoms are of course more marked in the double than in the single displacement, because in the latter case the normal joint is capable of bearing more than its share of the strain. The symptoms often increase during adolescence, but they may become less troublesome in adult life if a permanent resting-place on the pelvis is secured. This security is often assured, however, by a corresponding limitation of the range of motion. The physical signs of course persist and the individual is, as compared with the normal standard, more or less disabled and deformed. Fortunately the great majority of the patients are females, and because of the less laborious occupations and the distinctive dress, the disability and its effects are less serious than if the displacement were more equally divided between the sexes.

The symptoms of the anterior dislocation in which the head of the bone lies beneath the anterior superior spine, are less marked because the relation of the pelvis to the femur is nearly normal, so that secondary deformity is slight. The shortening is less and the resistance of the tissues attached to the anterior superior spine is sufficient to assure a more secure support than in the ordinary form so that the limp is less noticeable. In bilateral anterior dislocation there is a swaying backward of the body, but the exaggerated lordosis is absent.

DIAGNOSIS.—The diagnosis offers no difficulty. The history of the limp, at once apparent when the child began to walk, yet not accompanied by pain or preceded by injury or disease, is in itself sufficiently distinctive. If the displacement is of one side measurement demonstrates the shortening as compared with the other limb, a shortening that is explained by the prominence and the elevation of the trochanter above Nélaton's line. Traction and upward pressure on the leg will demonstrate the abnormal mobility of the displaced head; and finally if the thigh be flexed and adducted to its extreme limit, the neck and head of the femur can be easily distinguished moving under the gluteal muscles when the limb is rotated. Thus it may be differentiated from depression of the neck of the femur (coxa vara), in which although the trochanter is elevated, the neck and head of the bone cannot be felt, and in which the abnormal mobility, characteristic of the dislocation, is absent. Again, coxa vara is almost never a congenital affection, therefore the history itself would practically exclude it.

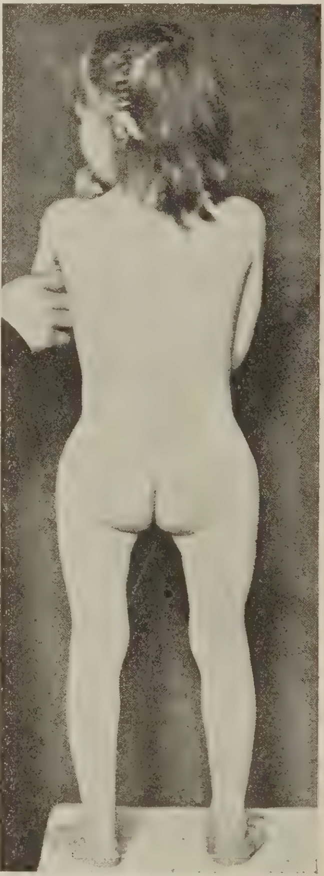

FIG. 2650.—Bilateral Dislocation Showing the Separation of the Thighs.

Upward displacement of the femur not infrequently follows infectious epiphysitis in infancy or early childhood. In such cases a part of the upper extremity of the bone is usually destroyed so that the head cannot be dis-

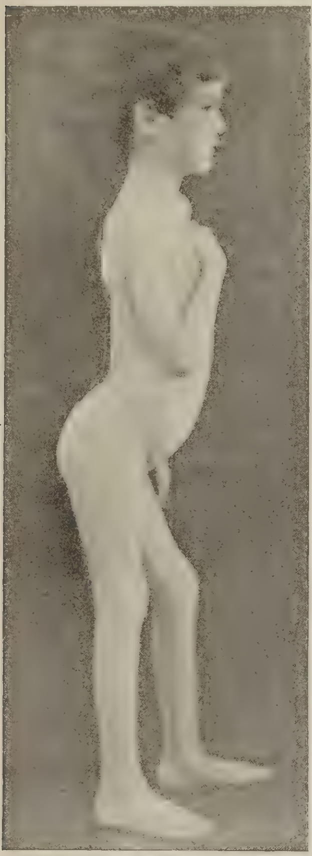

FIG. 2651.—Bilateral Dislocation Showing Habitual Flexion of the Thighs and the Increased Inclination of the Pelvis.

tinguished on palpation. Although the other physical signs are similar to those of the congenital displacement, the scars about the joint show the evidence of former disease and the history is almost always available for diagnosis, so that as a rule such disabilities as well as traumatic dislocations or other results of injury or disease are readily excluded.

Certain of the minor symptoms of congenital dislocation may be simulated by other affections, but these may be excluded readily by the physical examination.

In doubtful cases a Roentgen picture will demonstrate the character of the disability.

TREATMENT. — The principles of the treatment are simple, since it is evident that the only cure of a dislocation must be replacement of the displaced part. The application of these principles is difficult, however, because of the congenital or acquired abnormalities that may interfere with reduction or with the functional ability of the limb after treatment.

There are two methods of treatment by which cure or palliation may be attained. The first is forcible reduction without cutting, of which the most practicable method is that advocated by Lorenz, although this treatment was first advocated by Paci.

The Lorenz treatment is based upon the theory that if parts about the joint can be sufficiently stretched to allow the head of the bone to be brought into direct contact with the rudimentary acetabulum, and if it can be held for a sufficient time in this position, the weight of the body in walking, constantly forcing the bone against the substance that partly fills it, will gradually enlarge it to its normal capacity. Thus he calls it the "functional weighting" method, and this is its essential and vital distinction from the forcible correction of Paci, with which it is often confounded.

The steps of the operation are: 1. Elongation of the Limb. The trochanter must be brought down to the level of Nélaton's line or lower. This may be accomplished by preliminary traction in bed with heavy weights or by manual force at the time of operation, the latter means being efficient in young subjects. The child having been anæsthetized, a folded sheet is passed between the legs, the two ends of which are held by the assistant above the shoulder of the side to be operated on, or the assistant may clasp his hands about the perineum and thus fix the pelvis. In most instances counter-traction on the sheet by one assistant and fixation of the pelvis by another will be necessary. One then seizes the thigh and begins a series of alternate stretchings and relaxations, using gradually increasing force for from ten to twenty minutes, or until the resistance of the tissues is entirely overcome. The leg is then as long or longer than its fellow and lies limp in an attitude of abduction.

For this preliminary extension Lorenz often uses a powerful machine attached to the leg by means of a band about the ankle, but I am inclined to think that the manual method is to be preferred if one does not object to the labor that it involves.

2. Reposition. One now attempts to force the head of the femur over the ridge that represents the posterior margin of the acetabulum and through the opening in the contracted capsule.

The thigh is flexed to about ninety degrees in order to relax the capsule, and while the pelvis is fixed by an assistant, the limb is gradually and forcibly abducted; the resistance of the muscles being overcome by forcibly kneading the tense adductors with the ulnar border of the hand, as well as by the direct traction. During this manœuvre reduction often takes place, but in most instances this is facilitated by upward traction of the flexed limb with one hand, direct pressure being exerted on the trochanter with the thumb of the other hand. The limb is at the same time abducted, and the head of the bone is drawn and lifted over the posterior rim of the acetabulum. This partial reduction is accompanied as a rule by a distinct thud and shock, the limb remaining fixed; a position from which it may easily be displaced by reducing the abduction or flexion.

One now endeavors to make the reduction more stable by enlarging the capacity of the articulation. The forcible abduction is continued, the limb being forced outward until it is parallel with the table, or even behind the plane of the body. It is then forcibly rotated outward and inward. Finally, the patient is turned upon the sound side and the limb is moved up and down (like a pump handle), while strong pressure is exerted on the

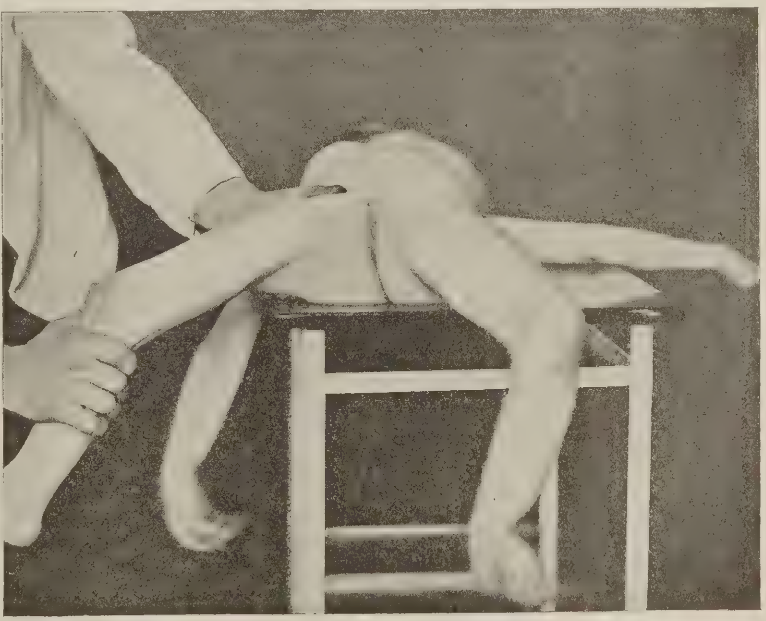

FIG. 2652.—The Typical Position in which to Fix the Limb After Reduction.

trochanter, the aim being to drive the head of the bone forward and inward completely within the capsule and to stretch its anterior wall which was drawn over, and was partly adherent to the acetabulum. The next step is to fix the limb in a position in which reluxation is impossible, the typical position being that already described of over-abduction from the original attitude of right-angled flexion of the thigh on the body. This position Lorenz describes as one of extreme abduction, extension and outward rotation, a description which is somewhat less intelligible to most readers than that adopted. In this attitude the head of the bone should be felt directly under the femoral artery, and it often forms a distinct prominence beneath Poupart's ligament. A short plaster spica bandage is then applied reaching to the knee where it is cut out sufficiently behind to allow flexion of the leg on the thigh. The body part of the spica may be of the usual form or made after the Lorenz method by figure-of-eight turns about the pelvis so that the iliac crests are firmly fixed. This pelvic portion, which is made at least one-half inch in thickness, is then cut out as in the illustration so that it does not restrict greatly the movements of the trunk. If greater fixation is required, as when it is difficult to hold the head of the femur in the acetabulum, the bandage may be extended below the knee, and as the neck of the bone is usually somewhat anteverted it is well at the same time to rotate the thigh slightly inward. When the reduction can be made easily and when the joint is evidently fairly secure, as in certain cases treated at an early age, it is unnecessary to exaggerate the normal range of motion, but it is better to fix the limb in an attitude of moderate flexion and abduction.

In the ordinary class of cases or up to the age of about four years, the reduction in the manner described is not especially difficult. In older subjects preliminary traction in bed until the muscular shortening is in great part overcome is indicated. In certain cases of this class preliminary tenotomy of the hamstrings, of the adductors, and of the muscles attached to the anterior superior spine is advocated by Lorenz, and when reduction is difficult he places a padded block under the trochanter in order to increase the leverage. In this older class, in which great force is necessary to accomplish reduction, a number of accidents have been recorded; for example, fracture of the neck of the femur, paralysis due to forcible stretching of the nerves, necrosis of soft parts, and several deaths from shock. As a rule, however, in the cases operated on within a reasonable limit of age, surprisingly little discomfort is experienced. There is usually some discoloration and swelling of the adductor region and discomfort lasting for several days, after which no complaint is made by the patient, who soon attempts to walk. If the limb is fixed in the ordinary position, that is drawn up to about a right angle with the trunk; a shoe with a cork sole two or three inches in height should be worn on the operated side. This first bandage should be kept in place for several months; in younger subjects as long as it is reasonably clean and efficient. When the second bandage is applied, if it is evident that the femur is still in place, the forced attitude is somewhat lessened, the limb is advanced slightly in front of the plane of the body and at the same time lowered to a moderate degree, the height of the shoe being correspondingly reduced.

In certain of the cases in which the foot can be brought to the floor, the high shoe may be removed, the pelvis being tilted downward to accommodate the attitude; thus more direct pressure is exerted upon the rudimentary acetabulum.

The second period of fixation corresponds to the first in time. Practically speaking, the limb is to be fixed in an attitude to guard against reluxation for from eight months to a year according to the character of the case. The fixation bandage is then removed. In successful cases the attitude of abduction and outward rotation often persists for a time. Massage and exercises, with the aim of strengthening the extensors and abductors of the thigh, are of service in the after-treatment.

By this method of treatment applied in a proper manner, a certain number of absolute cures may be attained (in nearly fifty per cent. of the cases Lorenz claims). This proportion is according to general experience far too large, and perfect cure in twenty-five per cent. of selected cases—that is, in patients five years of age or less—is perhaps nearer the true proportion.

In most instances what is really accomplished is a transposition, the head of the femur being forced forward to a position below the anterior superior spine. In many instances this failure is not apparent until the limb is brought to an approximately normal position, in others it is evident on removal of the first bandage. The reasons for failure, even when all the details of the treatment are carried out, are apparent:

1st. Failure to force the head of the bone through the constricted capsule.

2d. The very common anteversion of the neck of the femur that is practically always present in anterior displacements and in a large proportion of the other forms. Thus in the normal attitude the head of the bone cannot be retained in the acetabulum.

3d. Such deformity or non-development that adaptation of the parts is impossible.

The limit of age within which this operation may be

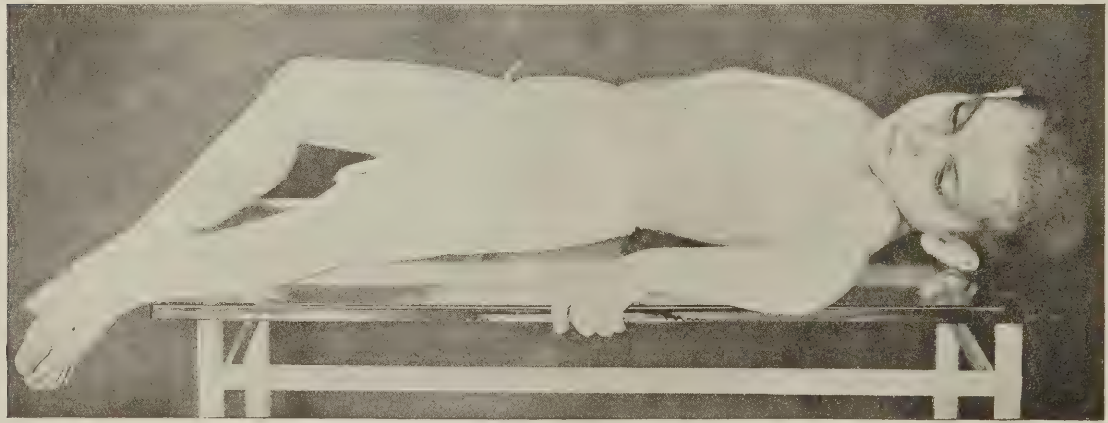

FIG. 2653.—The Lorenz Spica Bandage Illustrating the Typical Position During the Second Stage of the Treatment.

successful cannot be stated with certainty. It is evident, however, that the earlier it is undertaken the greater the chance of success. After the age of five years the difficulty of the manipulation is greatly increased and the chances of success are correspondingly lessened. It may be performed, however, as a preliminary to the open operation, even if the chance of success is small or with the aim of transposing the head of the femur and thus improving the condition of the patient. For such transposition which lessens the shortening and replaces the head of the femur in a relatively normal position, may be classed as a half cure.

The bilateral dislocation is far less favorable for treatment than the unilateral, because the chance of success is in any event lessened by half and because the congenital abnormalities appear to be more marked than in the unilateral class of cases. In young subjects both hips may be operated on at one time, although the resulting attitude is very awkward and walking is practically impossible. In older subjects on this account it is better to treat one hip at a time.

As has been stated, anterior displacements are practically always accompanied by a forward twist of the neck of the femur, anteversion. In such cases the limb must be fixed in an attitude of abduction and inward rotation, the distortion to be corrected later by osteotomy.

THE OPEN OPERATION.—As has been stated, one of the chief obstacles to successful reposition is the interposition of the capsule between the head of the femur and the acetabulum, the failure in other words to force the head through the constriction of the capsule.

In such cases or whenever the simple reposition has been unsuccessful the next step must be the open operation.

If the details of the Lorenz operation have been followed no preliminary treatment is required, but if the open operation is the primary procedure, all shortening of tissues must be overcome either by traction in bed or by forcible manipulation before the parts are exposed.

An incision is made from a point about half an inch to the outer side of the anterior superior spine, and is extended downward and slightly backward for about four inches; the fascia is divided and the line of junction between the tensor vaginæ femoris and the gluteus medius muscles is found. These muscles are then separated and are drawn to either side by retractors, exposing the capsule of the joint. The ilio-psoas muscle which often covers its anterior surface is separated from it, and the capsule is caught with a sharp hook and it is freely opened by an incision parallel to the neck of the bone. The finger is then passed through the opening down upon the rudimentary acetabulum. A strong cervix dilator is then inserted and the contracted capsule is thoroughly stretched. If the ligamentum teres is present it is removed. If on examination the acetabulum appears to be of sufficient size, the head of the bone is placed within it, the capsule is united, and the wound is closed with catgut sutures. A long plaster bandage is then applied and the further details of the ordinary noncutting method are carried out, except that if anteversion of the neck is present the limb must be rotated inward as well as abducted. In such cases when the first dressing is changed, or at a later time, an osteotomy of the shaft of the femur must precede the return of the limb to the normal attitude.

Osteotomy.—In order to control the head and neck of the femur a long drill is inserted through the trochanter and to a sufficient distance in the neck to fix it firmly. The child is turned upon the sound side and a sand bag is placed between the thighs. A small sharp osteotome is then inserted on the outer aspect of the thigh at a point just below the trochanter minor, and the femur is divided. The upper fragment being fixed in its place by the drill, the shaft of the femur is rotated outward until the normal relation is restored. In this attitude the plaster bandage is applied about the projecting drill. This is drawn out when the new position is assured, that is, at the expiration of a week or more.

The Open Operation with Enlargement of the Acetabulum (the Hoffa-Lorenz operation).—This operation is in principle that originally devised by Hoffa and modified by Lorenz, as the operation of routine for congenital dislocation, but which is now reserved for cases in which the simple reposition has failed or in which arthrotomy seems unlikely to be successful.

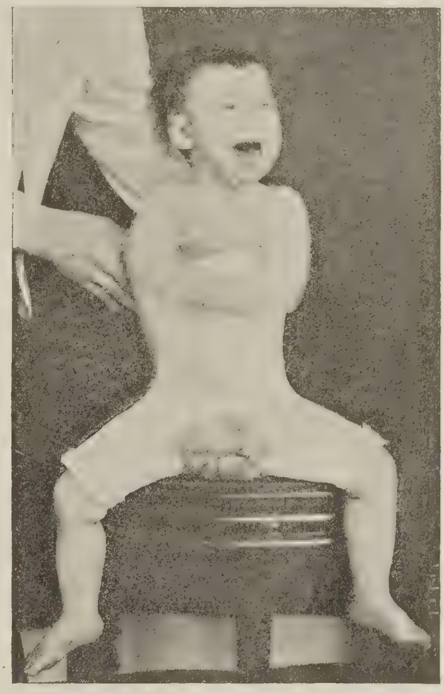

FIG. 2654.—Bilateral Dislocation, Showing the Less Extreme Attitude of the Limbs.

If when the joint is opened in the manner described the acetabulum is manifestly inadequate, it may be enlarged by removing with a strong sharp spoon the contents of the rudimentary acetabulum and deepening it to the normal size.

The head of the bone is then replaced and the stability of the articulation is tested by moving the limb in various directions. The wound is then closed or it may be temporarily packed with gauze according to Hoffa's method. A long plaster bandage is then applied, the limb being extended and slightly abducted. If anteversion of the neck is present the femur should be rotated inward and secondary osteotomy must be performed at a later time in the manner described. At the end of eight weeks a short spica bandage is substituted on which the child is allowed to walk about.

As might be expected, this operation is often followed by limitation of motion and by pain on manipulation, symptoms explained by the traumatism of the operation. In such cases, and in fact in the majority of cases, there is a strong tendency to distortion of the limb toward flexion and adduction. It is therefore in this class far safer to fix the limb in a proper attitude by means of the plaster bandage or other appliance until this tendency is overcome, in some cases for a year. In other instances the support may be dispensed with in a much shorter time. A removable apparatus which will allow massage, the use of hot air, and the like, is of course preferable.

When all the symptoms of discomfort have disappeared forcible movements under anæsthesia are sometimes of service in breaking up adhesions and increasing the range of motion. Special exercises to strengthen the weak extensors and abductors are of course indicated in all cases.

The advantages of this operation are that immediate replacement with comparatively small danger of reluxation is assured, while the limb remains in the normal attitude. The disadvantages are the limitation of motion or even ankylosis that may result.

Ankylosis following the operation in unilateral displacement, provided there is no distortion of the limb, is a marked improvement on the original dislocation, but bilateral ankylosis would practically disable the patient. For this reason one should await the result of the operation on one side before treating the other.

Ankylosis is, however, the exception, and in many instances practically normal, or at all events a sufficient range of motion remains. The degree of final disability depends in great part upon the after-treatment. If deformity is prevented, and if the muscles are strengthened by massage and by exercises, a practical cure may be attained, although in most instances a slight limp will persist even in favorable cases.

The danger of the open operation is slight in the hands of competent surgeons, less even than it is in the other method when great force is required to reduce the displacement, as in the treatment of older children.

In conclusion it may be said that the prospect of success in the treatment of congenital dislocation of the hip stands in direct relation to the age of the patient, since the extent of the pathological changes that make cure difficult or impossible depends in great degree, as in acquired dislocations, upon the duration of the disability. Consequently treatment should be applied as soon as the displacement is discovered, and there is little excuse for not making the correct diagnosis as soon as the child begins to walk. The treatment of selection before the age of six years is the functional weighting method of Lorenz. By this means a certain proportion of the cases may be cured, and in all instances the posterior may be changed into an anterior displacement, which makes the after-treatment much easier. If this treatment is ineffective it should be followed by the open method. In the younger patients simple incision and forcible stretching of the capsule may be sufficient, if the acetabulum is well formed; if not, it will be necessary to enlarge it to a sufficient size. Osteotomy may be necessary to correct anteversion of the neck of the femur whichever method is employed to reduce the displacement.

The treatment of congenital dislocation of the hip is not likely to be successful beyond the age of ten years, although in favorable cases it may be attempted. In exceptional cases at the age of adolescence or in adult life, the discomfort attending the dislocation may necessitate excision of the hip. In other instances adduction and flexion deformity may require osteotomy to correct practical shortening.

Other Congenital Dislocations.—Congenital misplacements at other joints are quite insignificant when compared with that at the hip, and in only two situations is the disability of sufficient importance to require especial consideration. These are the shoulder and the knee.

Congenital dislocation at the shoulder may occur in two forms, one in which there is actual misplacement before birth, and the other in which a dislocation is caused by violence at birth. In either case the displacement is almost always backward upon the dorsum of the scapula (subspinous). Thus the arm is abducted and rotated inward and there is the characteristic limitation of motion.

True primary displacement of either variety is rare. Many of the reported cases were apparently subluxations, secondary to the relaxation of the capsule of the joint and to the muscular atrophy caused by anterior poliomyelitis, or to the habitual malposition due to obstetrical paralysis.

Treatment.—The only treatment of a dislocation is replacement of the displaced bone if it be possible. If the displacement were discovered in infancy it might be possible to reduce it by manipulation and, unless the glenoid cavity were undeveloped, it might be retained in proper position. As a rule, however, the cases are not seen until later childhood when the accommodative changes are marked.

Phelps, of New York, has reported several cases of congenital dislocation of the shoulder, caused apparently by injury at birth, as they were accompanied by paralysis. In one case, that of a boy eight years of age, the joint was opened by a posterior incision along the border of the deltoid muscle. The head of the scapula was found to be atrophied, and the posterior margin of the glenoid cavity broken away. This, together with the contraction of the tissues on the anterior aspect of the joint, made it necessary to cut away a part of the head of the bone in order to replace it. The secondary depression on the scapula was excised and the redundant capsule was removed. The immediate result of the operation was very favorable. Phelps states that he has operated in two similar cases, but a final report of the results has not been presented.

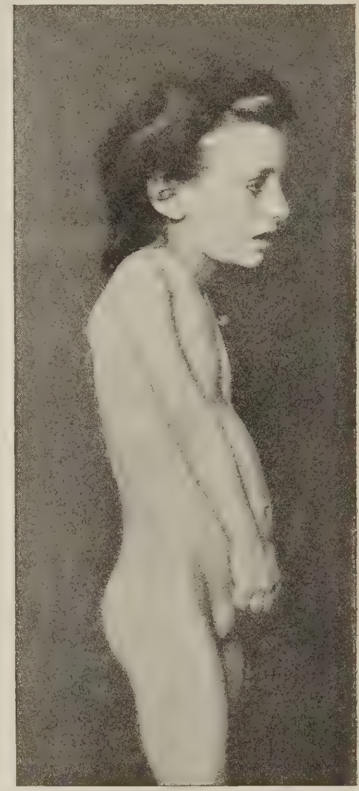
Fig. 2655.—Congenital Dislocation of the Right Shoulder.

It would seem, however, that as in a posterior displacement the contracted tissues must be those in front of the joint, an anterior rather than a posterior incision would be preferable. In all cases the open operation should be deferred until after the contracted parts have been stretched by manual force in the manner described in the treatment of congenital displacement of the hip.

Cases of congenital displacement in other directions are recorded, but these are so rare as to be of little practical importance.

Congenital Genu Recurvatum, or Anterior Displacement of the Tibia.—The most common of the congenital deformities at the knee is the so-called genu recurvatum, in which the knee is bent somewhat backward, or, in other words, the leg is hyperextended on the thigh. The deformity is often classed as an anterior dislocation, but there is no actual displacement, except in the extreme cases in which the tibia may be turned directly forward on the femur, even to a right angle or less. In the ordinary cases the range of extensionis merely exaggerated, while flexion is limited or checked, principally by adaptive shortening of the quadriceps extensor muscle.

The appearance in well-marked genu recurvatum is very peculiar; it is as if the patient's limb were reversed, the popliteal depression having become a prominence, the range of overextension representing apparently normal flexion. In such cases the leg may be brought to the straight line, but greater flexion is resisted by the retracted tissues, and when the pressure of the hand is removed the leg is drawn back to the deformed position by the contraction of the quadriceps extensor muscle.

Genu recurvatum is not infrequently accompanied by varus or valgus deformity at the knee, more often by the latter, and by laxity of the ligaments. In many instances the patella is absent or is rudimentary and not infrequently deformity is accompanied by malformations or defective development of other parts.

Etiology.—The deformity in cases of simple recurvatum may be explained by an abnormal and fixed position in utero, and in cases seen soon after birth the mechanism is clearly shown by the habitual attitude. The thighs are sharply flexed on the body, the dorsal surfaces of the hyperextended knees are in relation to the abdomen, while the feet may be brought into contact with the face or trunk according to the degree of deformity. The retarded development of the quadriceps extensor muscle explains the rudimentary patella which is often an accompaniment of the deformity.

Treatment.—The treatment of the hyperextended knee is very simple. It consists in massage of the atrophied and contracted muscle, combined with more or less forcible manipulation in the direction of flexion. If, as is often the case, the leg seems to be drawn forward by spasmodic muscular action, the methodical massage should be combined with the use of a simple posterior splint.

In the more extreme cases manual force may be applied under anæsthesia, and the deformity may be overcome at one or several sittings according to the resistance of the contracted parts. The leg is then fixed in a flexed position until the tendency to recurrence has been overcome. When the child begins to walk a light lateral brace may be necessary to insure perfect functional use of the joint, as in many instances laxity of ligaments and muscular weakness may persist for a time.

Rudimentary or Absent Patella.—As has been stated, a rudimentary patella is a frequent complication of genu recurvatum, or of any congenital defect or deformity of the knee or limb that involves imperfect development of the quadriceps extensor muscle. In many cases of this type it is impossible to distinguish the patella during the early months of infancy, but later a minute patella appears that slowly increases to an approximately normal size.

Absence of patella under the same conditions is less frequent, although Potel collected one hundred cases from literature.

Treatment.—The treatment of rudimentary patella is included in the massage and stimulation of the atrophied or rudimentary muscle with which it is usually associated, and the support that the weak or deformed knee may require.

Royal Whitman.

HIPPOCRATIC OATH.—The ancient Greek writings commonly called "The Works of Hippocrates of Cos" were judged even by ancient Greek critics to be really by various authors. The truth of this conclusion is plain to modern scholars. These writings have probably existed as in some sort a collection since the early days of the Alexandrine library near the beginning of the third century B.C.; and the composition of the several writings may safely be referred to the fifth or fourth century. Which of them are truly works of the famous physician whose name they bear is quite uncertain, as no direct contemporary testimony exists. Modern critics can only sift internal evidence, and compare the views of earlier critics, ancient, perhaps, but often naïve or biassed. Many writings in the collection, however, are plainly as old as Hippocrates, if not older. He was born in 460 B.C.; died, probably, in 377 B.C.; and was a worthy of the great period often styled that of Pericles. There is no proof, however, that Hippocrates was ever at Athens, though he was known there; and scarcely anything is known of his life with certainty.

One of the most famous writings of the Hippocratic collection is that entitled "The Oath." It is probably at least as ancient as Hippocrates, but that he composed it can neither be affirmed nor denied. Traces of its widespread influence occur in history; and by means of it modern physicians still hand down the traditions of their calling to those about to receive a medical degree. The ancient words do not accord with the changes wrought by twenty-two centuries in men, beliefs, and manners; but no modern words can be nobler, and the ancient thoughts are vital to the modern oath. The following translation of the Greek original into English is by the present writer:

THE OATH.

I swear by Apollo the Physician, and Æsculapius, and Hygeia, and Panacea, and all the gods and all the goddesses—and I make them my judges—that this mine oath and this my written engagement I will fulfil so far as power and discernment shall be mine.

Him who taught me this art I will esteem even as I do my parents; he shall partake of my livelihood, and, if in want, shall share my goods. I will regard his issue as my brothers, and will teach them this art without fee or written engagement if they shall wish to learn it.

I will give instruction by precept, by discourse, and in all other ways, to my own sons, to those of him who taught me, to disciples bound by written engagement and sworn according to medical law, and to no other person.

So far as power and discernment shall be mine, I will carry out regimen for the benefit of the sick, and will keep them from harm and wrong. To none will I give a deadly drug, even if solicited, nor offer counsel to such an end; likewise to no woman will I give a destructive suppository; but guiltless and hallowed will I keep my life and mine art. I will cut no one whatever for the stone, but will give way to those who work at this practice.

Into whatsoever houses I shall enter I will go for the benefit of the sick, holding aloof from all voluntary wrong and corruption, including venereal acts upon the bodies of females and males whether free or slaves. Whatsoever in my practice or not in my practice I shall see or hear, amid the lives of men, which ought not to be noised abroad—as to this I will keep silence, holding such things unfitting to be spoken.

And now if I shall fulfil this oath and break it not, may the fruits of life and of art be mine, may I be honored of all men for all time; the opposite, if I shall transgress and be forsworn.

The best Greek text (from which the foregoing translation was made) is that of E. Littré, "Œuvres complètes d'Hippocrate" etc., tome 4, Paris, 1844, pp. 628 to 632.

Many commentaries have been published upon the oath. Among these, special mention is deserved by Littré's Argument, *l. c.*, pp. 610 to 625; and by the notes of C. Daremberg, "Œuvres choisies d'Hippocrate," seconde édition, Paris, 1855, pp. 1 to 11.

The following matters require discussion, more or less brief:

Hygeia and Panacea were daughters of Æsculapius.

The distinction between "precept" and "discourse" (*παραγγελίης τε καὶ ἀκροήσιος*) has not been explained satisfactorily.

"Suppository" is perhaps as nearly equivalent as possible to the Greek word *πεσσός*, which doubtless means, in the oath, a sort of medicated pledget to be withdrawn after a longer or shorter time. Many formulæ for making such, for various purposes, are given in the Hippocratic collection.

The words "destructive suppository" (*πεσσὸν φθόριον*) refer to abortion. A parallel and fully developed phrase, viz., "a wine destructive to embryos" (*φθόριος ἐμβρύων* *οἶνος*) occurs in the Materia Medica of the later Greek physician Dioscorides, of the first century A.D. (Lib. v., cap. 77, ed. Sprengel, vol. i., p. 734). Although abortion is abjured without qualification in the oath, there were probably Greek practitioners of the time of Hippocrates who made a distinction similar to the modern one between justifiable and criminal abortion; for methods of emptying the uterus are frequently and quite simply referred to in the Hippocratic collection, though often expressly aimed at embryos styled "dead" or "livid" or "motionless" or "stricken" or "apoplectic."

But there is also good reason to believe that, in Hellas, the accepted line between guilt and innocence in the matter of abortion did not always coincide with that drawn nowadays. The clear recognition of the fact that the early embryo is from the instant of conception a human being, truly alive and possessing the right to live, even before the "quickening,"—this doctrine is entrenched in a maturer knowledge of physiology than the ancients could command. In the ideal State discussed in Plato's dialogue of "The Republic," certain embryos irregularly begotten were to be made away with before birth (ed. Stephanus, p. 461c). Plato was a younger contemporary of Hippocrates, and Plato's pupil, Aristotle, was born a few years before the death of the great physician, and was himself an Asclepiad, *i.e.*, a physician's son. Aristotle, in his "Politica," expressly recommends abortion in order to limit the number of children, but enjoins the procuring of it "before the advent of sensation and life." The presence of these he formally makes the criterion of "the hallowed" and the reverse in this matter (Politica, vii., cap. 16, ed. Ac. Boruss., p. 1335, b 19 to 26).

In the embryological treatise "On the Nature of the Child" in the Hippocratic collection, the author, who may not have been of Cos, but possibly an adherent of the rival school of Cnidos, describes a certain case as one of abortion at the sixth day deliberately procured by himself. The circumstances are given in detail, and plainly stamp the case as criminal according to modern ideas; but the author relates it without a trace of guilty consciousness, adhering, one may conjecture, to the doctrine of morals set forth by Aristotle (Hippocrates de Nat. Pueri, § 13, ed. Littré, vii., p. 488). The following striking passage both shows us "strict constructionists" of the Hippocratic oath nearly five hundred years after the death of Hippocrates, and sets forth explicitly, as current eighteen centuries ago, a view of the morals of abortion closely akin to that of modern physicians. The Greek gynæcologist Soranus of Ephesus was a practitioner at Rome under the emperors, not far from the time when Juvenal was scourging its vices with his satires in the earlier years of the second century A D. Referring to abortion, Soranus writes:

> There is a disagreement; for some reject destructive practices, calling to witness Hippocrates, who says, "I will give nothing whatever destructive," and deeming it the special province of Medicine to guard and preserve what Nature generates. Another party maintains the same view, but makes this distinction, viz.: that the fruit of conception is not to be destroyed at will because of adultery or of care for beauty, but is to be destroyed to avert danger impending at parturition, if the uterus be small and cannot subserve the perfecting of the fruit, or have hard swellings and cracks at its mouth, or if some similar condition prevail. This party says the same thing about preventing conception, and with it I agree. (Translated by the present writer from the Greek of Soranus, Gynæciorum Lib. i., cap. 19, ed. Rose, p. 229).

The abjuration of lithotomy in the oath contains the only mention thereof made in the Hippocratic collection. The ancient practitioners of medicine freely practised operative surgery; and no certain cause can be assigned for their refusal to cut for the stone. It has been shrewdly guessed, however, that the cause lay simply in the formidable dangers of a rude and uncertain procedure.

As the Hippocratic oath still plays a part in medicine worthy of its character and history, it has been thought proper to end this article with one of the modern adaptations. At the annual commencement of Columbia University in the City of New York, the following oath is administered to the graduating class of its College of Physicians and Surgeons:

Candidates for the Degree of Doctor of Medicine:

You do solemnly swear, each man by whatever he holds most sacred:

That you will be loyal to the Profession of Medicine and just and generous to its members;

That you will lead your lives and practise your art in uprightness and honor;

That into whatsoever house you shall enter, it shall be for the good of the sick to the utmost of your power, you holding yourselves far aloof from wrong, from corruption, from the tempting of others to vice;

That you will exercise your art solely for the cure of your patients, and will give no drug, perform no operation, for a criminal purpose, even if solicited; far less suggest it;

That whatsoever you shall see or hear of the lives of men which is not fitting to be spoken, you will keep inviolably secret.

These things do you swear? Let each man bow the head in sign of acquiescence.

And now, if you shall be true to this, your oath, may prosperity and good repute be ever yours; the opposite, if you shall prove yourselves forsworn.

In this oath, the words "that you will be loyal to the Profession of Medicine, and just and generous to its members," are from a formula at one time in use at the above-named medical school; for the rest of the foregoing adaptation the present writer is responsible.

John G. Curtis.

HIRUDINEA.—Among the Annelida or segmented worms the leeches form a well-marked order. The body of the leech is elongated, usually flattened dorso-ventrally, and provided with a prominent terminal or subanal sucker, while many forms possess also an anterior or oral sucker. The bristles all but universally present in annelids are here wanting save in a single genus, and the metamerism of the body presents a poorly marked external aspect although actually highly developed. The rings which appear in external view are mere surface markings, and are variably related to the true somites. Of the latter there are always thirty-four (thirty-five), of which those in the central portion of the body possess the typical number of annuli, while the first few and last few manifest ordinarily a reduction from that number. Prominent papillæ may usually be observed on the dorsal surface in the form of six or eight longitudinal rows; these are metameric sense organs known as sensillæ, and the eyes which vary in number in different forms are anterior units in certain of the rows. The annulus bearing the sensillæ is now generally regarded as the central one of the typical three- or five-ringed somites, and is the only one present in case of those somites manifesting the extreme of reduction. The leeches are hermaphroditic and the two sexual pores lie in the midventral line, the male in front of the female orifice.

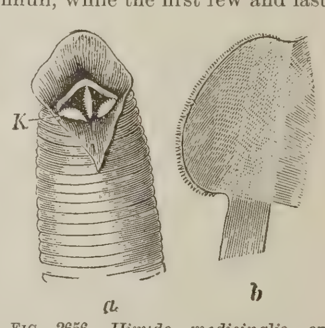

FIG. 2656.—*Hirudo medicinalis*, or European Leech. *a*, Ventral aspect of anterior end, showing an open mouth at the bottom of which the jaws, *K*, are visible; *b*, one of the jaws isolated, showing marginal denticles and muscles. (After Claus.)

The family of the Gnathobdellidæ, or Round-jawed Leeches, is characterized by three saw-toothed jaws in a simple pharynx (Fig. 2656); the typical somite has five annuli. Among the fresh-water leeches (Natantia), which have an eyeless ring between the third and fourth pairs of eyes, only the monostichodont forms (*i.e.*, those with a single row of teeth in each jaw) are important, and of these only two genera need be noticed here.

Hirudo L.—Either one hundred and one or one hundred and two rings with twenty-six metameres between the first pair of eyes and the sucker of which the first six and the last four are abbreviated. Buccal and post-buccal rings fused below; only three annuli in somite XXIII. Each jaw has from fifty to one hundred sharp-pointed teeth. Male genital pore between annuli 30 and 31, female between 35 and 36. First pair of nephridial pores ventral in ring 13, last in ring 93; seventeen in all.

Hirudo medicinalis L.—*Sanguisuga medicinalis* Savigny 1820, *S. officinalis* Savigny 1820, *H. officinalis* Derheims 1825. Length 100 to 200 mm.; breadth 10 to 30 mm. Jaws large, each with 80 to 90 teeth. Color variable, darker above than below, dirty yellowish-brown in tone with tendency to gray or green; at the margin a bright yellow or brown band with black margins; on the back three more or less prominent red longitudinal bands spotted with black (Fig. 2657).

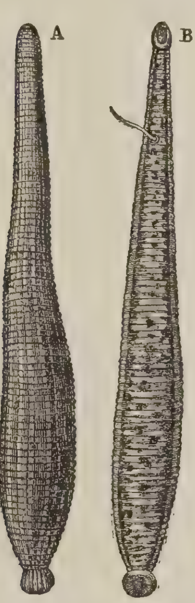

FIG. 2657.—*Hirudo medicinalis*, or European Leech. *A*, Dorsal aspect; *B*, ventral aspect. (After Railliet.)

This species is native in Europe, northern Africa and southwestern Asia, but at present is extinct in many regions and obtained by artificial culture or through importation only. Among the very numerous color varieties, as many as sixty-four being recorded by Diesing, two have been recognized as sub-species or varieties:

The Gray Leech, var. *medicinalis s. str.*, back greenish-gray with three russet-red lines on each side, of which the middle one, and often the inner also, shows a black spot on each metamere. Ventral surface greenish-yellow and spotted with black.

The Green Leech, var. *officinalis*, back darker green, often with black pigment more prominent, though red specimens also occur. Ventral surface almost entirely unspotted. A series of intermediate forms makes a distinction even between these two varieties difficult in many cases.

The leech sucks from four times its volume of blood for the young to three times in an adult, or from 6 to 15 gm. If, however, the sucking leech be cut in two by the shears close behind the pharynx, the blood streams out in pronounced pulsations and, as the sucking action is not interfered with, a stronger or rather longer-continued blood extraction is caused. During the ordinary operation of sucking a leech gives off a large quantity of clear fluid which exudes from the skin in drops. It is not blood serum, as often supposed, but the secretion of the nephridial canals. While this exudation ceases at the end of ten days, the assimilation of the stomach contents of the leech demands from twelve to eighteen months. At the end of two months, however, the animal manifests willingness to bite, but its full appetite is not yet restored. On the other hand, the leech can fast for two years or more and may be kept indefinitely without food in suitable leech jars. A fast of from six to eight months is necessary before re-employment; but the latter is not advisable. Before the third year of their growth leeches are not used for medicinal purposes, and from eighteen to twenty years has been put as the probable length of life. For the method of using leeches, see *Blood-letting*.

At one time the enormous demand for leeches reached, for example, 7,000,000 per year in London alone, but in recent years their use for therapeutic purposes has greatly diminished, no doubt largely as the result of occasional fatal cases and in spite of certain evident advantages for local affections. Fatal bleeding has been known where the bite opened a large vessel (*vena cruralis* or *jugularis*), or in internal organs where the leech, by careless application at the nasal fossæ, vagina, or rectum, has penetrated or been drawn too deeply into the organ. In order to guard against this leeches should be fastened in such cases by a thread passed through the middle of the posterior sucker. Several authors have investigated the reputed transmission of disease, particularly bacterial, by leeches, but uniformly with negative results. So far as bacteria are concerned, the species studied were rapidly digested in the stomach of the leech, and the entrance into the wound of such as may be upon the lips at the start appears difficult under the circumstances of the blood flow.

Where native, these, like other large leeches, attack men and animals invading swamps and pools, and in recorded instances with fatal results to children or young animals.

Hirudo troctina Johnson 1816, often confused with the medicinal leech, is distinguishable by its smaller size, 80 to 100 mm. in length by 12 to 18 mm. in breadth, and especially by the scantier number of teeth, about seventy, in each jaw. It is native in northern Africa and Spain, perhaps also Italy and Sicily, and is exported in large numbers to France, England, and America. In power to extract blood it is much inferior to *H. medicinalis*.

Hirudo nipponica Whitman 1886, also smaller in size than *H. medicinalis*, is common about Tokyo, Japan, and in other parts of the island. Its habits and use conform closely to those of the continental species. Other species of similar habit are reported from different regions of the Orient; they are, however, only poorly known.

The genus *Limnatis* may be distinguished from *Hirudo* by the papillæ on the jaws and by the ventral furrow traversing the entire length of the anterior lip of the oral sucker. One species, *Limnatis nilotica* Sav., demands brief notice. It is native in the circummediterranean region, and in some places is so abundant as to become a veritable pest. Especially the young, described by Moquin-Tandon as *Sanguisuga ægyptiaca*, are often swallowed accidentally in drinking and may remain for a long time fixed in pharynx, choanæ, œsophagus, trachea, or even stomach. The species plays accordingly an important rôle in diseases of man and domestic animals in northern Africa during the hot season. European soldiers in garrison, and even natives, in spite of their precautions, suffer from the leech, which evokes by its presence both local and general symptoms of serious character if assistance is not speedily afforded. With the removal of the worms rapid and complete healing of the wounds and disappearance of secondary symptoms occur almost immediately and without exception. The removal may be accomplished by instruments from those organs where the leech can be seen; in deeper locations copious application of salt water is said to be efficacious. This leech can pierce only the mucous membranes of higher animals, and its inability to penetrate the external skin, even of children, has often been demonstrated. Other species of this genus have a more powerful bite, and are used especially in the East for medicinal purposes, even though they take up less than half as much blood as *Hirudo medicinalis*. In this country *Macrobdella decora*, one of the large native leeches, is employed in some places for blood-letting; it may be recognized by the following description:

Macrobdella Verrill 1872. Cephalic lobe smaller than in *Hirudo*. Annuli 103; at least four in somite XXIII.

Neither buccal nor post-buccal annuli united on the ventral side. Both genital orifices in somite XI., and behind them a group of prominent copulatory glands.

Macrobdella decora Verrill.—*Hirudo decora* Say 1824, *H. decora* Leidy 1868. Jaws with about sixty-five teeth, copulatory glands opening by four pores in a quadrate figure on the last annulus of XIII. and the first two of XIV. The first annulus of XXVI. is divided marginally and sometimes also dorsally into two annuli.

This species is widely diffused in fresh waters of the United States, having been reported from Maine to Minnesota and from Pennsylvania to Kansas. It is frequently used instead of imported leeches by physicians and is said to be equally efficacious, although its capacity is somewhat smaller, only about 5 gm. It is so powerful, however, that serious results have followed its attacks upon the legs of children wading in its haunts.

Among the land leeches which form a special section, Reptantia, of this family, and are distinguished by the absence of an eyeless ring between the third and fourth pair of eyes, a few forms deserve brief mention.

Hæmadipsa Tennent. Body almost round, sucker separated only by a slight constriction. Near the sucker auriculæ with the pores of the last pairs of nephridia. Typical metamere with five annuli.

Hæmadipsa zeylanica Moq.-Tand.—*H. japonica* Whitman. Length 20 mm., or in extended form 60 mm., diameter of body behind 6 mm., in front 2 mm.; sucker 5 to 7 mm. in diameter. Annuli ninety-seven; male genital pore between annuli 30 and 31, female between 35 and 36. In each jaw ninety incurved teeth.

The animal, when gorged, has the form of a flask of about 10 mm. in diameter at its largest part, while the neck measures only 2 or 3 mm. in thickness. The color is exceedingly variable, and yet five or six varieties may be recognized, one of which, var. *japonica* Whitman, known in Japan as the mountain leech, is common in the entire Indomalayan region, China, and Japan. It has long been known on the island of Ceylon, where it forms a veritable pest to natives and Europeans alike. The leeches appear in immense swarms, particularly in moist regions and during the rainy season, and at all levels from the coast up to 4,000 feet, although they occur even as high as 15,000 feet in the Himalayas. During the dry season they hibernate in the earth; at other times they live in moss among stones and on shrubs and trees. The approach of large animals brings them out in myriads; they move with surprising activity, and springing on the unfortunate passer-by they suck often for hours before falling off. No clothing is close enough to protect man from their attacks, and during army manœuvres they have inflicted large losses on European troops, attacking the soldiers even when asleep. Accounts of travel in Ceylon abound in narratives of the ferocity of these pests, and recent writers from the Philippines comment on their activity in that country in equally forcible terms. It is probably this species, and very likely the variety *japonica*, which is reported by Blanchard as abundant in the Philippines, to which the trouble is due, although other species of *Hæmadipsa* manifest, no doubt, similar habits of life.

The bite is not poisonous, as often maintained, but the large number of wounds and careless treatment afford abundant opportunity for secondary infection of a serious character. Among the natives of Ceylon one may see many deformities induced by these leeches, which are accordingly feared more than serpents and carnivores.

An allied form, *Phytobdella Meyeri* R. Bl., is also recorded from Luzon.

The family of the Rhynchobdellidæ, or proboscis leeches, is characterized by a protrusible pharynx, while the typical metamere consists of three annuli and jaws are lacking. Few of these forms are able to penetrate the human skin, but among those of sufficient power are especially American forms, which appear as occasional parasites of man and in some regions are used for therapeutic purposes. The two species of importance are both members of the following genus, which is restricted to the warmer regions of the American continent:

Liostoma Wagler 1831—*Hæmenteria* de Fil. 1849. Body broad and flattened; back covered with many prominent papillæ; the first and third ring of each somite from VI. to XXII. inclusive split on the ventral surface so that on the ventral surface the space occupied by five pseudo-annuli corresponds to that occupied by the three adjoining dorsal annuli. Male genital pore between annuli 26 and 27, female between 28 and 29. Two pairs of eyes so closely set that they appear as a single pair.

Liostoma Ghilianii R. Bl.—*Hæmenteria Ghilianii* de Fil. 1849. Length of alcoholic specimen 190 mm., breadth 100 mm., corresponding to a probable length while living of 350 to 400 mm. Annuli seventy, together with three preocular; the first seven annuli form the oral sucker.

This giant form inhabits the basin of the Amazon and the swampy regions of Guiana. Blanchard reports that it attacks horses and cattle, and a few individuals are sufficient to kill even a full-grown animal.

Liostoma coccineum Wagler 1831—*Hæmenteria officinalis* de Fil. 1849, *H. mexicana* de Fil. 1849, *Glossiphonia granulosa* Jimenez 1865. Length 80 mm., breadth 22 mm. Annuli seventy, with two preocular; the first six annuli form the oral sucker (Fig. 2658).

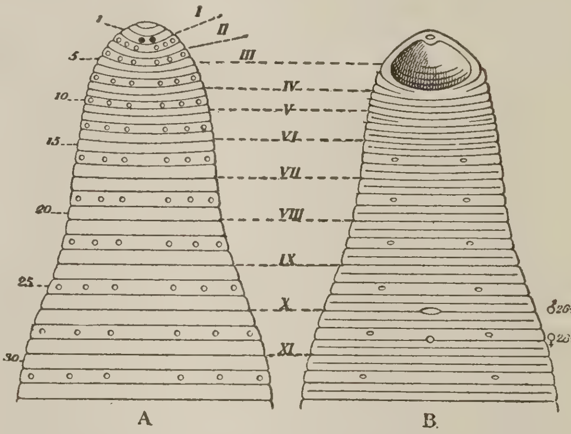

FIG. 2658.—*Liostoma coccineum*, or Mexican Leech. Diagrammatic view of anterior somites, *A*, from dorsal surface with eyes and sensillæ, *B*, from ventral with nephridial and sexual pores. (Modified from Blanchard.)

The range of this species extends from Mexico to Paraguay through Central and South America. In Mexico it is universally used as the medicinal leech. In some instances, however, its bite appears to be accompanied by serious results. There are noted almost immediately a feeling of general lassitude and an unpleasant itching and twitching, succeeded soon by general urticaria, and in a short time apoplectic symptoms are manifested; but cases occur in which the cerebral congestion or the urticaria is wanting. Most authors incline now to the belief that these symptoms are due to the salivary secretion poured into the bite by the leech, and yet it seems also clear that some predisposition on the part of the individual is also a prerequisite. Brandes suggests that the symptoms of poisoning are manifested only in persons exhibiting hyperæsthesia, and attributes the rare cases of serious illness following the application of *Hirudo medicinalis* in Europe to the same sensitive constitution. (Compare in this connection the effects produced by the bite of *Argas*, as reported by Brandes and noted in the article *Arachnida*, Vol. I., p. 437.)

In spite of these accidents this is actually the only species used for medicinal purposes in Mexico, sufficient evidence of its generally satisfactory character. In some provinces (Guadalajara) the leech is regularly cut in two after it has taken hold in order to measure definitely the quantity of blood extracted. *Henry B. Ward.*

PRINCIPAL ARTICLES USED.

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Castle, W. E.: The Metamerism of the Hirudinea. Proc. Am. Acad., vol. xxxv., No. 15, 1900.

Leuckart, R.: Die Parasiten des Menschen, etc., zweite Aufl., Lief. 5, 1894; Lief. 6 (Nach dem Tode des Verf. bearb. v. Dr. G. Brandes), 1901.

Verrill, A. E.: Synopsis of the North American Fresh-Water Leeches. Report United States Fish Com. for 1872–73, p. 666, 1874.

Whitman, C. O.: The Leeches of Japan. Quar. Jour. Mic. Sci., vol. xxvi., p. 317, 1886.

Also shorter papers by the same authors, Leidy, J. P. Moore, and others.

HISTOLOGICAL TECHNIQUE.—METHODS OF STUDYING LIVING AND FRESH TISSUE.—For observations on living tissue, we now make use of the cold-blooded animals almost exclusively; and, on account of the convenience, use the tails of amphibian larvæ, and small fishes and frogs. For holding these small animals, while under observation, the larva holder of Schulzer (Fig. 2659) will be found very convenient. The head of the animal is placed under the edge, *a*, the tail is spread out on the bevelled plate, *b*, and covered with a cover-glass. The cell holds sufficient water to cover the animal. To keep the animal quiet, we wrap it loosely in a piece of cloth, leaving the gills free, or add a few drops of ether to the water. If the observations are to be continued for any length of time, provision must be made for the renewal of the water. This can be accomplished by any of the usual methods of irrigation.

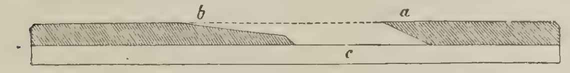

FIG. 2659.—Schulzer's Larva Holder.

For observations on the frog, it is necessary to paralyze the animal with curare. A slight nick is made in the skin over the posterior part of the head, and two or three drops of a one-twentieth-per-cent. solution of curare* is injected into the dorsal lymph sac by means of a long, slender pipette introduced through the above nick. The exact amount of curare to be used will depend upon its quality and the size of the animal, and can be determined only by experiment. In the course of a few hours the animal will become completely paralyzed, while the vegetative functions continue, the necessary amount of oxygen being supplied by cutaneous respiration.

We utilize for these observations:

1. *The Web.*—The advantage of this part of the animal is that we do not inflict any injury, consequently we are not likely to meet with any disturbances of the vital processes; but, on account of it not being very transparent, it is inferior to other parts. A frog poor in pigment should be selected, and after being wrapped in a moist cloth it is laid on an oblong sheet of cork, in one end of which a hole, at least 15 mm. in diameter, is made; at the edges of this hole four or five pins are stuck, to which bits of soft string attached to the toes are tied, spreading the web out over the hole. The cork is now placed on the stage of the microscope, and the web is moistened at intervals to prevent its drying.

2. *The Tongue.*—For observations on this and other organs of the animal, Professor Thoma has invented a series of frog plates, which are shown in Fig. 2660. The one in the centre of the figure is for the tongue; that on the left for the mesentery; that on the right for the lung and bladder. These plates consist of a bed plate, *a*, of brass, covered by a thin sheet of hard rubber. At *B* is an opening, which varies in the different plates, covered with a thick glass plate on which the organ to be examined is placed. At some distance from this glass plate runs the brass rim, *c*, *c*, *c*, 7 mm. high, which by a proper inclination conveys the irrigating fluid, as it flows off the organ, to the tubes, *d*, *d*, to which are attached rubber tubes leading to a vessel for receiving the waste fluid. The supports, *t*, are for holding the irrigating cannula, *g*. They are pivoted to the plate, and move on a perpendicular axis; to the upper end is attached a short split tube, which is tightened by a small screw; this is connected with the support by a hinged joint, allowing it to be moved on a horizontal axis. In this tube is placed the glass irrigation cannula, *g*. It will be noticed that in the tongue and mesentery plates two supports are provided. This is to allow of the use of two cannulæ, one for irrigating the upper, and the other the under, surface of the organ. At *e* is a perpendicular rod for supporting the ring holding the cover-glass. At each side of the plates (in the tongue plate it is at the end) is a notched support, *k*, for holding the rubber tube attached to the cannulæ introduced into the different organs for inflation, etc. Between the rim, *c*, *c*, *c*, and the plate, *B*, bits of cork are wedged for pinning out the organs.

For examining the tongue, the animal is placed on the plate belly down, and the nose is brought close to the edge of the glass plate; the tongue is drawn out over the plate, and fastened to the bits of cork by pins which are cut off short.

3. *The Mesentery.*—Male frogs are to be used, so that the examiner may not be embarrassed with the ovaries. An incision is made through the skin, on the side, from the pelvis nearly to the axilla. After all hemorrhage has ceased, the abdominal cavity is opened by an incision of 10 to 20 mm. in length; a coil of intestine is drawn out carefully over the glass plate so that it will fall upon the bits of cork, to which it is pinned, leaving the mesentery spread out in a thin layer on the glass plate.

4. *The Bladder.*—A glass cannula (*B*, Fig. 2661) is filled with a three-fourths-per-cent. salt solution, and the rubber tube closed with a bit of glass rod. The cannula is now inserted into the cloaca, and directed forward into the bladder; it is held in place by a thread passed through the skin over the sacrum and tied around the cannula. An incision, similar to the one for the mesentery, is made in the side of the animal. The glass rod is removed from the rubber tube, and the latter is raised slightly so

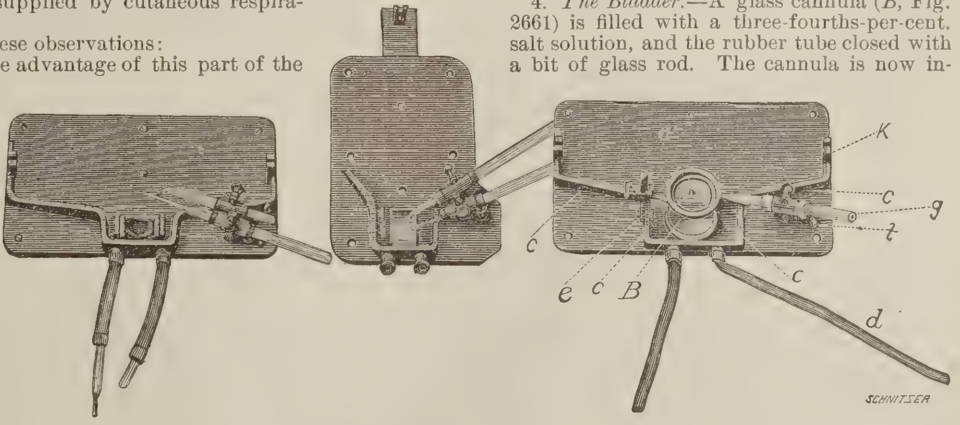

FIG. 2660.—Thoma's Frog Plates.

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* S. H. Gage recommends the following solution: Curare, 0.2 gm.; ninety-five-per-cent. alcohol, 20 c.c.; water, 20 c.c. Grind up the curare in a mortar with the water and alcohol. Do not filter.

as to cause the fluid to flow into the bladder, distending it. The animal is now placed on the frog plate, and by gentle manipulation with the handle of a scalpel the distended organ is brought upon the glass plate and further distended if necessary; the glass rod is now replaced in the rubber tube, and the latter fixed in the support (*k*, Fig. 2660). The animal is covered with a bit of moistened filter paper, and the frog plate is placed on the microscope.

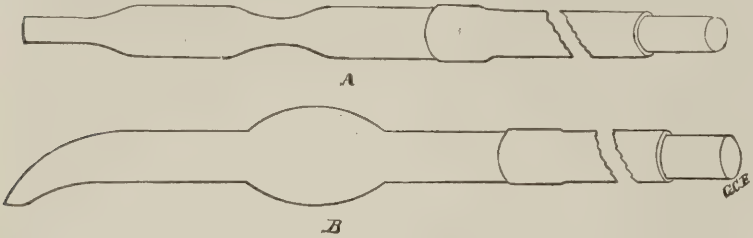

FIG. 2661.—Inflation Cannulæ.

5. *The Lung.*—The cannula (*A*, Fig. 2661) is introduced through the epiglottis, and held in place by a thread passed through the nose and tied around the constriction of the cannula. An incision, carried well into the axilla, is made through the skin on the side of the animal, and when all hemorrhage has ceased the thoracic cavity is opened. The operator should now remove the bit of glass rod from the end of the rubber tube attached to the cannula, and gently blow into the same, when the distended lung will be forced through the incision. The animal is placed on the frog plate, and the distended lung brought upon the plate *B*. In Fig. 2662 is shown the arrangement of the frog plate on the microscope, and the irrigating bottle. The stage of the microscope is to be inclined so as to cause the irrigating fluid to flow away. The bottle attached to the ring stand, filled with a three-fourths-per-cent. salt solution, is closed tightly with a rubber cork, through which pass two glass tubes. To one is attached a rubber tube, which is connected with the glass cannula (*g*, Fig. 2660) and conveys the irrigating fluid. The other is for regulating the pressure, which can be varied by raising or lowering the tube. The flow from the end of the irrigating cannula should be by drops, at short intervals, and is regulated by the pressure in the bottle, the size of the opening in the point of the cannula, and, if necessary, by a spring clip placed on the rubber supply-tube.

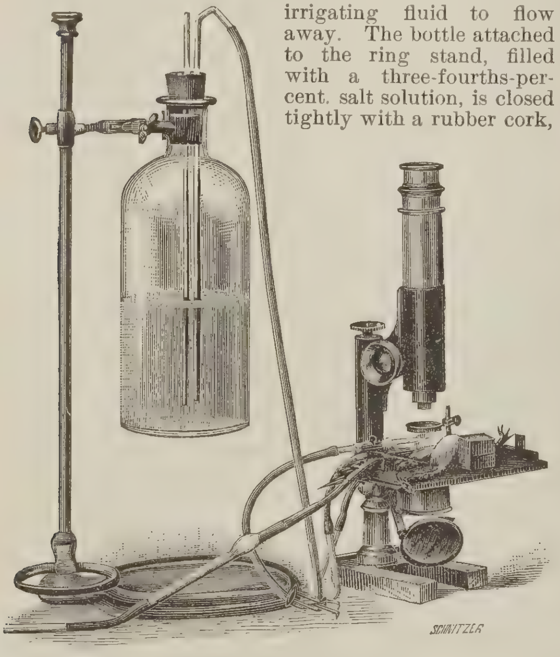

FIG. 2662.—Frog Plate and Irrigating Apparatus.

Fresh tissues are to be examined in the fluid that bathes them during life, or in a fluid that will change them but little if at all. Such fluids are known as indifferent fluids, and resemble in composition the natural fluids of the body. They are as follows:

Aqueous Humor of the Eye.—Obtained by puncturing the cornea of a recently killed animal, and allowing the aqueous humor to escape.

Blood Serum.—The blood of a recently killed animal is poured into a tall glass cylinder and allowed to coagulate. After coagulation has taken place, the upper margin of the clot is separated from the sides of the vessel, to permit it to sink; the vessel is allowed to stand for twenty-four hours, and the clear serum is then drawn off with a siphon, care being taken not to disturb the clot.

Iodized Serum.—Prepared by adding to every 1,000 c.c. of blood serum, obtained as above, 10 c.c. of tincture of iodine. This fluid alters the tissues slightly and stains them yellow. Instead of blood serum, amniotic or pericardial fluid may be used, but it must be absolutely fresh.

Artificial Serum.—This is to be used only when the natural serous fluids cannot be obtained. It is prepared by dissolving 2 gm. of sodium chloride and 28 gm. of egg albumen in 250 c.c. of distilled water, and adding 2.3 c.c. of tincture of iodine; the solution is then filtered.

Salt Solution (three-fourths per cent.).—Made by dissolving 7.5 gm. of perfectly dry, chemically pure sodium chloride in 1,000 c.c. of distilled water. This solution alters fresh tissues but slightly.

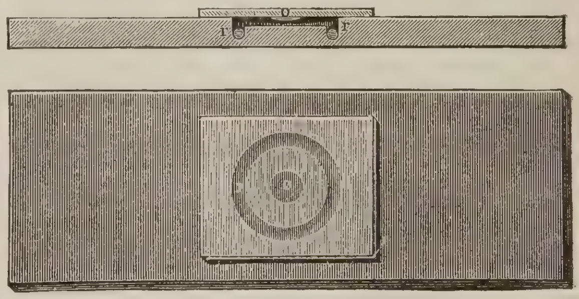

FIG. 2663.—Moist Chamber.

Fresh, thin membranes can be examined in one of the above solutions without any previous preparation. Bits of organs, fibres, etc., are to be teased on a slide, in a drop of one of the indifferent solutions, or sections can be made by the freezing microtome.

In observations on fresh tissue it is necessary to prevent evaporation, and in most cases pressure. The first can be prevented by painting a ring around the cover with oil or vaseline; the latter by placing a hair between the cover and slide; or we may use the moist chamber.

In Fig. 2663 is shown a moist chamber. In the centre of a thick glass slide is cut a cavity, around the circumference of which is a groove (*rr*). The latter is filled with water; the specimen is placed on the cover-glass (*o*), or in the middle of the cavity.

METHODS OF APPLYING REAGENTS.—*Application of Fluids, Irrigation.*—A drop of the reagent is placed on the slide in contact with the edge of the cover-glass, and on the opposite side of the cover a bit of filter paper. The latter sucks out the fluid, which is replaced by the reagent flowing in on the other side. This process of irrigation can be continued for any length of time, if the reagent be renewed as it becomes exhausted, and the filter paper as it becomes saturated.

Application of Vapors and Gases.—A simple way of applying a volatile reagent to a specimen is to put a drop of such reagent in a cell on a slide, and invert a cover-glass, on which the specimen has been placed, over it. For gases it is necessary to use a gas chamber. Such a piece of apparatus is shown in Fig. 2664.

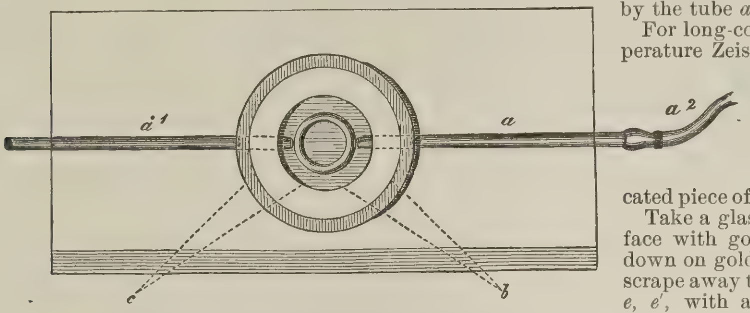

FIG. 2664.—Stricker's Gas Chamber.

It consists of a thick glass slide, in the upper surface of which is ground out a circular cavity. Two glass tubes are cemented into the two half-canals. The tube a is connected by an india-rubber tube, a^2, with the gas generator, and conducts the gas to the chamber; the other, a^1, serves for its exit.

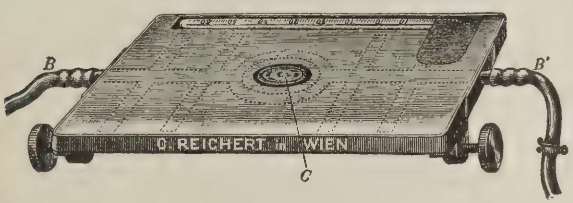

FIG. 2665.—Warm Stage.

Application of Heat.—Fig. 2665 shows the latest form of warm, stage in which hot water, used for heating, or which, by the use of ice water, may also be converted into a refrigerating slide. The central opening C (Fig. 2665) permits the passage of light. At each end of the slide a small tube, B, B', is inserted, by means of which it is connected with a vessel of water.

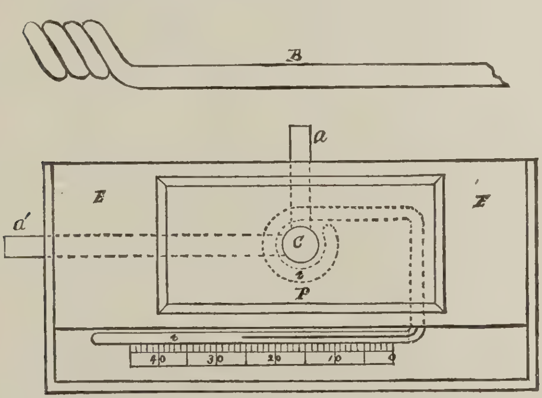

FIG. 2266.—Stricker's Warm Stage and Gas Chamber.

In Fig. 2666 is shown a combined warm stage and gas chamber. It consists of a rectangular piece of ebonite, E, E, fixed to a brass plate that rests on the stage of the microscope. On the upper surface of the ebonite is a brass plate, P, with an opening in the centre, C, leading into a brass tube, closed below by a piece of glass. For heating, the copper wire is placed on the tube a, the temperature of the plate being indicated by the thermometer t. The gas is conducted into the chamber by the tube a', while a serves as an exit.

For long-continued observations at an elevated temperature Zeiss' warm chamber (Fig. 2667) for enclosing the microscope should be employed.

Application of Electricity.—For the application of the electric current to specimens, the slide shown in Fig. 2668 will answer as well as a more complicated piece of apparatus. This can be made as follows:

Take a glass slide 27 × 127 mm., and cover the surface with gold size; press the moist surface firmly down on gold-leaf or tinfoil; allow it to dry, and then scrape away the metal so as to leave the two triangles e, e', with an interval, a, between their apices, of about 5 mm. for the object. The specimen is placed at a, and covered with a cover-glass. For transmitting the current the ends of the slide are clamped by the clips c, c', to which the wires leading from the battery are attached.

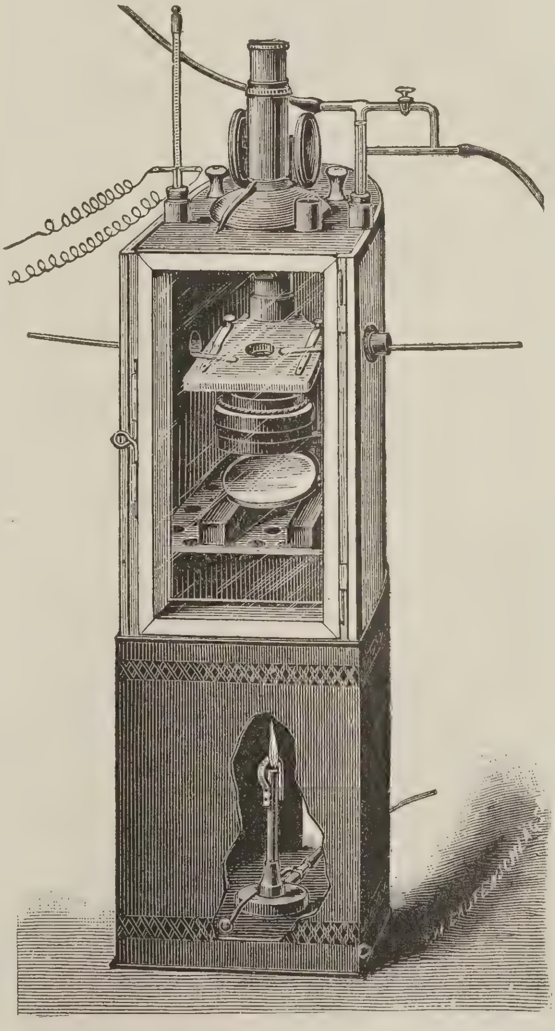

FIG. 2667.—Zeiss' Warm Chamber.

In Fig. 2669 is represented a combined moist chamber and electric slide. The slide, *s*, is covered with tinfoil, *f*, on its upper and lower surfaces, the foil on the upper surface being carried to the upper edge of the glass cell, *c*, which is cemented to the slide. The slide is placed on the copper supports, *k*, *k*, that are attached to the stage, *p*, if it be a glass one; if not, they must be insulated by strips of hard rubber. Two small strips of foil are cemented to the cover-glass, leaving a space of 5 mm. between the ends. The bottom of the cell is filled with a few drops of water; the specimen is placed on the cover-glass, in contact with the tinfoil, and the cover is inverted and placed on the cell, *c*, so that the foil comes in contact with that covering the cell. The electric current is conducted to the specimen through the metal supports by wires placed in the holes in their ends.

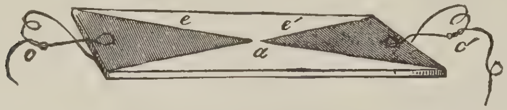

FIG. 2668.—Gold-leaf Electrodes.

METHODS OF FIXING, HARDENING, AND PRESERVING.—By the term "fixing" is meant the rapid killing of the tissue elements, so that they are preserved in nearly the same condition, as regards form and structure, that they had during life. The process of fixing also partially hardens the tissue, so that it is not injured by the subsequent manipulations.

The process of fixing produces optical differentiation in the tissues causing alterations in their indices of refraction. The index is raised in varying degrees, some elements being more affected than others, thus producing optical differences that were not present in the living tissue.

The fixation causes a coagulation of certain tissue elements rendering them insoluble, the fixing agent entering into chemical combination with them. At times these chemical compounds are soluble and are removed in the process of washing. Some of the insoluble compounds form mordants to certain stains, giving differential stainings. Some of the chemicals used for fixing prevent the subsequent staining of the tissue unless they are removed by special treatment. This is especially so when osmic or chromic acid is used.

A perfect fixing reagent should meet the following requirements: It should penetrate rapidly; it should kill quickly, without having an injurious action on the tissue; it should not dehydrate, as the withdrawal of water causes shrinkage; it should not interfere with the subsequent staining.

Of the numerous reagents used for this purpose, there is not one that meets all of the above requirements. Some cause shrinking, others more or less swelling, while others fix nuclear structures well but not cytoplasm, or *vice versa*. By combinations of several fixing agents, the faults of one may be counterbalanced by those of another.

The following rules should be observed in the use of fixing solutions: The size of the specimen should be *small*, averaging about 0.5 c.c. in bulk, and the quantity of fluids should be *large*, as much as a hundred times the bulk of the specimen.

The specimen should be removed from the fixing fluid as soon as it has been thoroughly penetrated by the latter. This depends upon the fixing agent used, and on the size and density of the specimen. Usually from twelve to twenty-four hours is a sufficient time for proper fixation.

In some instances it is desirable to fix an entire organ. In such cases the fixing fluid is injected through the artery and allowed to flow from the vein for from one to two hours, after which the entire organ is immersed in a large quantity of the fixing fluid.

After the specimen has been fixed it is to be washed in running water until all of its fixing agent has been removed. The specimen is then further hardened in graded alcohols.

Hardening.—After the fixative has been thoroughly removed from the specimens they are then hardened by passing them through graded alcohols, beginning with sixty per cent. and increasing the strength by about ten per cent. at the end of each twelve hours until strong alcohol, ninety-five per cent., is reached.

Absolute alcohol as found in commerce varies from 98 to 99.5 per cent.; it is very expensive, and it is almost impossible to keep it up to the proper strength after it has been exposed to the air. An alcohol that will meet all the requirements of absolute alcohol may be prepared after the plan of Ranvier: Cupric sulphate is pulverized and heated at a temperature of 100° C. until all the water of crystallization is driven off, and a white powder is the result. A glass-stoppered bottle is filled about one-third full with this powder, anhydrous cupric sulphate, and ordinary alcohol is added. After standing for twenty-four hours, the surface of the copper will have become decidedly blue, from the absorption of the water from the alcohol. A test made at this time will show the alcohol to be over ninety-nine per cent. Fresh alcohol is added, from time to time, until all of the copper has become blue in color, when it is no longer of any use for dehydration. The supernatant alcohol is now poured off, and the bottle placed in a hot-air sterilizer at a temperature of 100° C. until the cupric sulphate is again rendered anhydrous.

Commercial alcohol usually tests about ninety-five per cent. and is known as strong alcohol. The graded alcohols used in hardening are prepared by diluting this strong alcohol with water. The amount of water to be added to each one hundred volumes of ninety-five-per-cent. alcohol is as follows: For making 60-per-cent., add 41.5 volumes of water; 70-per-cent., 21 volumes of water; 80-per-cent., 6.5 volumes of water; 90-per-cent., 5.5 volumes of water.

All fixing agents if allowed to act long enough will harden the tissues, but as a general rule their prolonged action renders the tissues brittle.

Preservation.—For preserving the tissues after hardening, eighty-per-cent. alcohol is to be used, as prolonged immersion in strong alcohol interferes with the subsequent staining of the specimens.

Osmic Acid is a very volatile substance, its vapor being extremely irritating to the conjunctiva and nostrils. It is found in commerce in glass tubes, each containing 1 gm. or 0.5 gm. of the crystals. It is used in aqueous solutions of the strength of 0.1 to 2.0 per cent., or in combination with other acids in the proportion of 1 to 10,000.

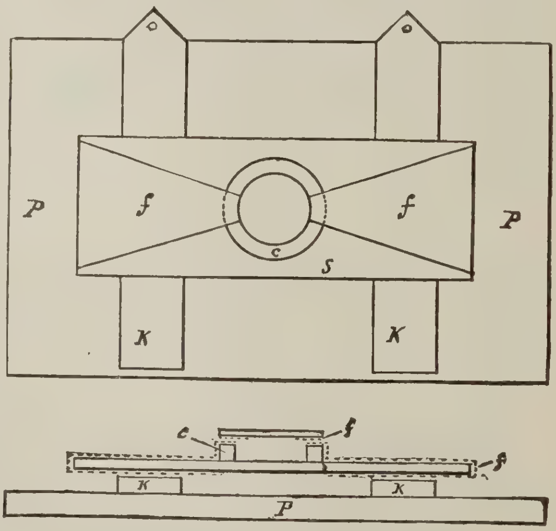

FIG. 2669.—Electric Slide and Moist Chamber.

For making a solution, a bottle is thoroughly washed with sulphuric acid, then with distilled water, that all traces of organic matter may be removed; then the label is removed from the tube, and the tube is washed in sulphuric acid and distilled water; the tube, its two extremities being broken off, is now put into the bottle, and the proper amount of distilled water is added to make a solution of the required percentage. The solution is to be kept in a well-stoppered bottle protected from the light. According to Cori this solution will keep perfectly, if enough potassium permanganate be added to give the fluid a slight rosy tint. As the fluid becomes colorless small quantities of the permanganate should be added to restore the tint.

Solutions that have deteriorated by the reduction of the osmic acid may be restored by the addition of a few drops of hydrogen peroxide.

Osmic acid is more valuable as a fixing than as a hardening agent. It fixes cytoplasm perfectly, nuclei badly. Its penetrating power is but slight, so that exceedingly small pieces of tissue must be used, and even then its action will be confined chiefly to the superficial parts. The vapor of osmic acid has a much greater penetrating power.

Tissues to be submitted to the action of the vapor are pinned out on a cork, fitted to a wide-mouthed bottle, in which there are a few cubic centimetres of a one-per-cent. solution of the acid, and allowed to remain until they become of a brownish color. After fixing, the excess of the osmic acid must be thoroughly removed by washing in running water. Any acid remaining will cause an over-blackening and it will also interfere with the subsequent staining.

Any over-blackening is best removed by immersing the tissue in a mixture of one part of hydrogen peroxide and twenty-five parts of seventy-per-cent. alcohol (Overton).

Osmic acid stains fatty matter black and is used as a stain for fat.

For increasing the penetrating power of osmic acid, Kolossow uses a one-half-per-cent. solution in a two- or three-per-cent. aqueous solution of uranium nitrate. Lately he has recommended the following mixture: Absolute alcohol, 50 c.c.; distilled water, 50 c.c.; hydric nitrate, 2 c.c.; osmic acid 1 to 2 gm. This mixture, he states, keeps well.

Chromic Acid.—Chromic acid is an exceedingly deliquescent salt, and in the presence of organic matter is readily reduced to the sesquioxide. It should be kept in ten-per-cent. aqueous solution, which may be readily diluted to the required strength for use.

It is used in aqueous solutions of one-tenth to one per cent. as a fixing agent, and allowed to act for a few hours only. For fixing nerve tissue, solutions of one-fiftieth to one-eighth per cent. are used. The pieces of tissue should be small, and after removal from the fluid should be well washed in water and preserved in eighty-per-cent. alcohol.

Mayer rinses the fixed material in water and then places it in seventy-per-cent. alcohol in the dark; the alcohol is changed daily until it ceases to become colored by the chromic acid; then the tissue is hardened in strong alcohol. Any chrome compound that may be present in the sections is removed by soaking the sections in 100 c.c. of seventy-per-cent. alcohol, to which is added four to six drops of hydric chloride. After being in this mixture for a short time the sections become perfectly white and stain well with the usual stains.

As a hardening agent, chromic acid is used in aqueous solutions of one-sixth to one-half per cent. It is very slow in its action, taking weeks, and even months if the specimen is large. As a rule, the pieces of tissue must be small, 2 to 3 cm. on a side, and the quantity of fluid large, 200 c.c. for each cubic centimetre of tissue. The fluid must be renewed at the end of the first, third, and fifth days. After the hardening is completed the specimen is placed in water for a day or two, to remove all traces of the acid, and then preserved in alcohol. After partial hardening in chromic acid, the action can be completed in alcohol, care being taken thoroughly to wash out the former before placing the specimen in the latter. Two or three weeks' immersion in the acid will be sufficient if the hardening is to be completed in alcohol.

The action of chromic acid seems to be analogous to that of tanning. The acid enters into combination with the tissues, rendering them tough like leather. A prolonged action of the acid will render them brittle.

Chromic acid has the property of softening bone, and is often used as a decalcifying agent. The acid is an excellent hardening agent for the central nervous system, nerve tissue, glandular tissue, and epithelium.

Chromic Acid and Alcohol.—Klein used a mixture of two parts of a one-sixth-per-cent. solution of chromic acid and one part of alcohol for his investigations on cells, and claims that it gave better results than the ordinary reagents, even osmic acid.

Urban Pritchard uses the following mixture: Chromic acid 1 gm., water 20 c.c., alcohol 180 c.c. The chromic acid is dissolved in the water and added to the alcohol. This was used for hardening the cochlea.

Chromic and Picric Acids.—A mixture of ten parts of a saturated solution of picric acid, twenty-five parts of a one-per-cent. solution of chromic acid, and sixty-five parts of water makes an excellent hardening fluid. Its action is slow.

Chromic Acid and Platinic Chloride (*Merkel's Fluid*).—This is recommended by its originator as an excellent fixing agent, especially for the retina. The formula is: Platinic chloride, 1 gm.; chromic acid, 1 gm.; water, 800 c.c. The specimen is to be kept in this fluid for from two to three hours, then preserved in alcohol. Eisig allows specimens to remain three or four hours in this fluid, and then preserves them in seventy-per-cent. alcohol. Specimens so treated stain well with almost any stain.

Chromic and Osmic Acids.—Flesch recommends the following mixture: One-per-cent. solution of osmic acid 10 parts; one-per-cent. solution of chromic acid, 25 parts; water, 65 parts. Specimens remain in this mixture for from twenty-four to thirty-six hours. The hardening is completed in alcohol and the specimen is preserved in the same.

Chromic and Acetic Acids.—One-per-cent. solution of chromic acid, 20 to 25 c.c.; one-per-cent. solution of hydric acetate, 10 c.c.; water, 70 c.c. This solution is recommended by Flemming when the after-staining of the specimen is to be effected with hæmatoxylin. These preparations do not stain well with aniline dyes.

Chromic and Formic Acids.—Ralb adds from four to five drops of formic acid to 200 c.c. of a 0.33-per-cent. solution of chromic acid. This mixture must be prepared fresh at the time of using. Small pieces of tissue are fixed for twenty-four hours and then washed in water.

Flemming's Fluid.—First Formula: Chromic acid, 0.25 gm.; osmic acid, 0.1 gm.; hydric acetate, 0.1 c.c.; water, 100 c.c. Second Formula: Chromic acid, one-per-cent. aqueous solution, 15 parts; osmic acid, two-per-cent. solution, 4 parts; hydric acetate, 1 part.

Small pieces of tissue are fixed in this fluid for from twelve to twenty-four hours, then well washed in running water and hardened in graded alcohols. These fluids were used by Flemming in his investigations on cell division. They fix the nuclear structures perfectly, but the cytoplasm not so well.

Fol's Modification.—Osmic acid, one-per-cent. solution, 2 parts; chromic acid, one per cent. solution, 25 parts; hydric acetate, two-per-cent. solution, 8 parts; distilled water, 68 parts.

Carnoy's Modification.—Osmic acid, two-per-cent. solution, 16 parts; chromic acid, two-per-cent. solution, 45 parts; hydric acetate, 3 parts.

Hermann's Modification.—Chromic acid, one-per-cent. solution, 12 to 15 c.c.; hydric acetate, 1 to 2 drops; osmic acid, 0.25-per-cent. solution, 8 to 10 drops.

Vanlair's Modifications.—I. Osmic acid, one-half-per-cent. solution, 40 parts; chromic acid, one-half-per-cent.

solution, 140 parts; hydric acetate, 10 parts. II. Osmic acid, one-half-per-cent. solution, 10 parts; potassium dichromate, one-half-per-cent. solution, 10 parts; hydric acetate, 2 parts.

Hermann's Fluid.—This is a modified Flemming's fluid in which platinic chloride is substituted for the chromic acid; its composition is as follows: Platinic chloride, one-per-cent. aqueous solution, 15 parts; osmic acid, two-per-cent. solution, 2 parts; hydric acetate, 1 part.

Potassium Dichromate.—The action of this salt is similar to that of chromic acid. It is used in aqueous solutions of one to two per cent. for fixing, and two to five per cent. for hardening. Its action is slow, and it has the advantage of never rendering the tissues brittle.

Müller's Fluid.—This fluid was first introduced by H. Müller for hardening the retina. It is an excellent hardening fluid for the majority of tissues, especially for the central nervous system. Its action is slow, but its penetrating power great. It requires a month to six weeks to complete the hardening of a spinal cord. If the temperature of the fluid is kept at 30° to 40° C., the time is reduced to from eight to ten days (Weigert).

The composition of the fluid is as follows: Potassium dichromate, 2 to 2.5 parts; sodium sulphate, 1 part; water, 100 parts. It should be used in large quantities, renewed at the end of twelve hours, then every third day until the hardening is completed. Then wash well in water and preserve in alcohol. (See Orth's fluid under Formalin Mixtures.)

Kultzschitzky recommends the following for fixing the gastro-intestinal canal: Potassium dichromate, 2 gm.; mercuric chloride, 0.25 gm.; hydric acetate, two-per-cent. solution, 50 c.c.; alcohol, 50 c.c. Some of the dichromate precipitates out, so the fluid must stand for a few days and then be filtered. The specimen is to be fixed for from three to five days; then washed in water and hardened in graded alcohols.

Dichromate-osmic-platinic Mixture (Lindsay Johnson). Potassium dichromate, 2.5 gm.; osmic acid, two-per-cent solution, 10 c.c.; platinic chloride, one-per-cent. solution, 15 c.c.; hydric acetate, 5 c.c.; water, 70 c.c. Dissolve the dichromate in the water and then add the other ingredients. This mixture is an excellent fixing fluid for the most of tissues, though used first by Johnson for the retina.

Erlicki's Fluid.—This is also an excellent hardening fluid for the central nervous system. It consists of potassium bichromate, 2.5 parts; cupric sulphate, 0.5 part; water, 100 parts. At a temperature of 30° to 40° C. it hardens the spinal cord in four days.

Tellyseniczky's Fluid.—Potassium dichromate, 3 gm.; hydric acetate, 5 c.c.; water, 100 c.c. Small pieces of tissue in this fluid are fixed for from one to two days and then washed well in water. This is an excellent fixative for cytoplasm and fair for nuclear structures.

Ammonium Dichromate.—This is used in one to two per cent. solution in water, in place of the previous salt, for hardening the central nervous system. If 1 c.c. of ammonia be added to each 100 c.c. of potassium dichromate solution, the color changes to a bright yellow, and its power of penetration is increased.

Ammonium Chromate (*Neutral Chromate*).—As a fixing agent this salt is used in five-per-cent. solution, and allowed to act for twenty-four hours. The specimen should afterward be washed well in water and preserved in alcohol.

Picric Acid.—Used in cold saturated solution in water, 1 part of picric acid to 86 parts of water at a temperature of 15° C. The bits of tissue must be small—1 to 2 cm. on a side for each 100 c.c. of fluid. The solution must always be in a state of saturation; to accomplish this a few picric-acid crystals are placed in the bottle, and the latter is shaken occasionally. After fixing, the tissues *should always be washed in alcohol and not in water.* A few drops of a saturated solution of lithium carbonate in water, added to the alcohol, will hasten the process.

This reagent acts by gradually transposing the albumin into an insoluble compound, so that tissues harden in it entirely without shrinking. As the tissues become less solid than with other reagents, it is necessary to complete the hardening in alcohol. The majority of tissues are stained yellow, but the color is withdrawn by alcohol, water, glycerin, etc.

Picro-acetic Acid.—Bolles Lee recommends a saturated solution of picric acid in a one-per-cent. solution of hydric acetate.

Boveri dilutes a saturated aqueous solution of picric acid with two volumes of water and adds one per cent. of hydric acetate.

These solutions are recommended for fixing cellular elements.

Picro-chromic Acid (Fol).—Saturated aqueous solution of picric acid, 10 parts; chromic acid, one-per-cent. aqueous solution, 25 parts; water, 65 parts. At the time of using add 0.005 gm. of osmic acid.

Picro-hydrochloric Acid (Mayer).—Water, 100 parts; hydric chloride, 8 parts; picric acid to saturation.

Picro-nitric Acid (Mayer).—Water, 100 parts; hydric nitrate, 5 parts; picric acid to saturation.

Picro-sulphuric Acid (Kleinenberg).—Distilled water, 100 parts; hydric sulphate, 2 parts; picric acid to saturation.

Picro-mercuric Chloride (Mann).—Picric acid, 4 gm.; mercuric chloride, 15 gm.; tannic acid, 6 to 8 gm.; alcohol, 100 c.c. Recommended for all animal tissues. Fix for twenty-four hours at the body temperature of the animal, then wash in iodine alcohol.

Picro-platinic-Osmic Acid (von Rath).—Saturated aqueous solution of picric acid, 200 c.c.; platinic chloride, 1 gm. dissolved in 10 c.c. of water; hydric acetate, 2 c.c.; osmic acid, two-per-cent. solution, 25 c.c.

Picric Alcohol (Altman).—Picric acid, 2.5 gm.; alcohol, ninety-five per cent., 35 c.c.; water, 70 c.c.

Picric Alcohol (Gage).—Picric acid, 2 gm.; alcohol, ninety-five per cent., 500 c.c.; water, 500 c.c.

Fix in the above solutions for from one to two days. Wash out in graded alcohols.

Picro-formalin (Graf).—Graf recommends the following solutions for cytological work:

1. Sat. aq. sol. picric acid, 1 vol., Formalin, 5 per cent., 1 vol.
2. " " " " " 1 " " 10 " " 1 "
3. " " " " " 1 " " 15 " " 1 "
4. " " " " " 95 vols., " full strength 5 vols.
5. " " " " " 90 " " " " 10 "

Small pieces of tissue are fixed for thirty minutes; then washed for one hour in a large quantity of thirty-per-cent. alcohol; then in fifty-per-cent. alcohol; seventy-per-cent. alcohol; eighty-per-cent. alcohol; and finally preserved in ninety-five-per-cent. alcohol.

Picro-Formalin—Platinic Chloride (Bouin).—Platinic chloride, one-per-cent. aqueous solution, 20 parts; picric acid, saturated aqueous solution, 20 parts; formalin, 10 parts; formic acid, 5 parts.

Palladium Chloride.—Employed by Waldeyer in one-thousandth-per-cent. aqueous solution, with the addition of a few drops of hydric chloride to aid in the solution, for softening the cochlea. The specimen is placed in this solution for twenty-four hours, and then in absolute alcohol for the same length of time.

F. E. Schulze uses this salt in 0.01 to 0.2 per cent. solutions. As the penetrating power is slight, small pieces of tissue are to be used—a piece the size of a bean to 30 c.c. of the solution. The hardening is completed at the end of thirty-six to forty-eight hours, but the specimen may remain in the fluid for months without harm. This solution stains protoplasm dark yellow, striated muscle brownish yellow, smooth muscle straw yellow, medullated nerves black. Hyaline membranes and elastic fibres stain slight yellow and remain transparent. Interstitial substance of connective tissue remains colorless, and will stain deeply with carmine and other stains, while the tissue colored by the palladium remains unstained. Sections are to be well washed in water and mounted in glycerin.

Fraenkel recommends the following as a fixative for connective tissue: Palladium chloride, one-per-cent. aqueous solution, 15 parts; two-per-cent. solution of osmic acid, 5 parts; and a few drops of acetic acid.

Mercuric Chloride is an excellent fixing agent. It kills rapidly and does not interfere with the subsequent staining of the tissues. It is slow in penetrating so that small pieces of tissue must be used. As a fixative it is used in saturated aqueous solution (about seven per cent.); or in saturated solution in three-quarters-per-cent. solution of sodium chloride. The simple aqueous solution does not keep well, depositing after a time a fine white precipitate. This precipitation can be prevented by the addition of a slight amount of hydric nitrate (Bolles Lee).

A better fixation is obtained if a small quantity of hydric acetate, about one per cent., be added to the aqueous solution. Bolles Lee speaks highly of a saturated solution of mercuric chloride in five-per-cent. hydric acetate. Van Beneden uses a saturated solution in twenty-five-per-cent. hydric acetate.

The specimens should be left in the fixing fluid as short a time as possible. A prolonged immersion renders them brittle.

After fixation, the tissues are washed in seventy-per-cent. alcohol, to which tincture of iodine is added until the alcohol becomes of a mahogany color. If the alcohol becomes decolorized more iodine is added, and this is repeated until the alcohol ceases to lose color. Finally the specimens are washed in eighty-per-cent. alcohol to remove the iodine. This procedure must be followed with all specimens that have been fixed in a fluid containing mercuric chloride. They are then preserved in ninety-per-cent. alcohol, in which after prolonged immersion they become very brittle.

Alcoholic Solutions of Mercuric Chloride.—Mercuric chloride is more soluble in alcohol than in water, so that by the use of this menstruum a stronger solution may be obtained.

Gilson's Fluid.—Absolute alcohol, 1 part; hydric acetate, glacial, 1 part; chloroform, 1 part; mercuric chloride, to saturation. Small specimens are fixed for from twenty-five to thirty seconds, then washed in alcohol (see above).

Ohlmacher's Fluid.—Absolute alcohol, 80 parts; chloroform, 15 parts; hydric acetate, glacial, 5 parts; mercuric chloride, to saturation (about twenty per cent.). Small pieces of tissue are fixed for from fifteen to thirty minutes, and then washed out in iodine-alcohol.

Lang's Fluid.—First Formula: Mercuric chloride, 3 to 12 gm.; sodium chloride, 6 to 10 gm.; hydric acetate, 6 to 8 c.c.; distilled water, 100 c.c. Second Formula: Saturated solution of mercuric chloride in picro-sulphuric acid, to which is added five per cent. of hydric acetate.

Carnoy's Modification of Lang's Fluid.—Mercuric chloride, 5 gm.; sodium chloride, 5 gm., hydric acetate, 5 c.c.; water, 100 c.c.

Pacini's Fluid.—Mercuric chloride, 1 gm.; hydric acetate, 2 c.c.; water, 300 c.c.

Zenker's Fluid.—Mercuric chloride, 5 gm.; potassium dichromate, 2.5 gm.; sodium sulphate, 1 gm.; hydric acetate, 5 c.c.

The hydric acetate is added just before using. The specimen is fixed for from two to forty-eight hours; washed well in water, then in graded alcohols, and finally in ninety-per-cent. alcohol to which is added from one-half to three-quarters per cent. of tincture of iodine. This is an excellent fixing fluid, especially for muscular tissues. Tellyseniczky states that it is equal to Flemming's fluid for cellular structures.

Apathy's Fluid.—Alcohol, fifty per cent., 100 c.c.; sodium chloride, 0.5 gm.; mercuric chloride, 3 to 4 gm.

Rath's Fluid.—Alcohol, 200 c.c.; mercuric chloride, 1 gm.; hydric acetate, glacial, 2 c.c. Fix for from four to five hours.

Alcohol is used for the purpose of fixing tissues either in the form of one-third alcohol, "alcohol au tiers" of Ranvier, or absolute alcohol. The one-third alcohol consists of 1 part of ninety-per-cent. alcohol and 2 parts of water. Tissues are placed in this fluid for twenty-four hours; then stained in an alcoholic staining fluid. They should never be treated with an aqueous medium, except picrocarmine, alum carmine, or methyl green.

Absolute alcohol penetrates quickly and fixes fairly well, but there is apt to be some distortion on account of shrinkage. It hardens at the same time. Except in a few special cases alcohol should be discarded as a fixative and its use restricted to hardening and preserving.

ALCOHOLIC MIXTURES.

Carnoy's Fluids.—I.* Hydric acetate, glacial, 1 part; absolute alcohol, 3 parts. II. Hydric acetate, glacial, 1 part; absolute alcohol, 6 parts; chloroform, 3 parts.

The chloroform in the second formula makes its action more rapid.

Zacharias' Fluid.—Hydric acetate, glacial, 1 part; absolute alcohol, 4 parts; one-per-cent. solution of osmic acid, 2 to 3 drops to each 10 c.c. of the above.

Fix for from one to three hours in the above mixtures and then wash out in alcohol. These fluids give good fixation of mitotic figures and of the central nervous system.

Alcohol and Osmic Acid (Vignal).—Alcohol and one-per-cent. osmic acid, equal parts. After fixing wash in eighty-per-cent. alcohol.

Formalin.—Formalin is a forty-per-cent. solution in water of the gas formaldehyde (HCOH), an oxidation product of methyl alcohol. It is also known in commerce as "formol" and "formalose." The commercial product rarely tests over thirty-eight per cent. When exposed to the air a partial decomposition takes place with the formation of a white deposit, paraformaldehyde. The vapor of formalin is irritating to the mucous membranes. It also has an irritating effect on the skin, hardening it and causing the formation of annoying cracks which do not heal unless the hands are kept from coming in contact with the formalin.

Formalin penetrates rapidly and kills quickly, but unfortunately in most instances does not fix the tissue elements sufficiently to enable them to withstand the subsequent manipulations without change. On account of this fault pure formalin has been almost entirely abandoned as a fixative, but the agent is quite extensively employed in mixtures.

As a fixative it is used in the strength of from one to five per cent. In five-per-cent. solutions I have found it to be a good fixative for cystic tumors of the ovary, also for the mucous membrane of the uterus.

Bolles Lee has called attention to what he considers an inaccurate manner of stating the percentages used. He claims that the proper way of stating the strength of the solutions is to say "formalin diluted with so many volumes of water." It is now understood that when a percentage is given it means the stated percentage of commercial formalin and not of the gas formaldehyde.

The following is a table for formalin solutions:

100%	formalin	= 40%	formaldehyde		
50%	"	= 20%	"	= 1 vol. formalin	+ 1 vol. water.
25%	"	= 10%	"	= 1 " "	+ 3 " "
12½%	"	= 5%	"	= 1 " "	+ 7 " "
10%	"	= 4%	"	= 1 " "	+ 9 " "
5%	"	= 2%	"	= 1 " "	+ 19 " "
2½%	"	= 1%	"	= 1 " "	+ 39 " "
1%	"	= 0.4%	"	= 1 " "	+ 99 " "

As a preservative agent for gross specimens, formalin is used in the strength of from two to ten per cent., a five-per-cent. solution usually giving the best results. The weaker solutions cause more or less swelling of the tissues.

The quantity of the fluid should be large—one hundred times the volume of the specimen—and the fluid should be renewed at the end of twenty-four hours. In cases of large specimens it is well to renew the fluid a second or even a third time.

When used in this manner, formalin preserves the form and to a certain extent the natural color of the specimens. In some cases the blood color appears to be bleached out, but if the specimen is placed in strong alcohol, this is nearly if not entirely restored.

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* This is also known as Van Gehuchten's fluid.

For preserving the blood color of specimens, Johres makes use of the following procedure and fluid: Sodium chloride, 1 part; magnesium sulphate, 2 parts; sodium sulphate, 2 parts; water, 100 parts. To this mixture are added from five to ten parts of a forty-per-cent. solution of formalin. After the specimen has become sufficiently hardened, the formalin solution is poured off, the specimen is washed in ninety-five-per-cent. alcohol, then kept in ninety-five-per-cent. alcohol until the blood color becomes restored, and finally is preserved in a mixture of equal parts of glycerin and water.

A ten-per-cent. solution of formalin is the best hardening reagent for eyes. The cornea remains translucent and the vitreous humor retains its natural transparency perfectly.

For hardening the central nervous system it is used in the strength of from four to ten per cent. Sections stain well with Weigert's hæmatoxylin method.

Formalin Mixtures.—For fixing purposes formalin is now used almost entirely in combinations with acids and chemical salts.

Lovdowsky's Fluids.—I. Distilled water, 20 c.c.; alcohol, ninety-five per cent., 10 c.c.; formalin, 3 c.c.; hydric acetate, 0.5 c.c. II. Distilled water, 30 c.c.; alcohol, ninety-five per cent., 15 c.c.; formalin, 5 c.c.; hydric acetate, 1 c.c.

These fluids are recommended by Lovdowsky for fixing the mitotic figures of cells.

Cox's Fluid.—Mercuric chloride, saturated aqueous solution, 30 parts; formalin, 10 parts; hydric acetate, 5 parts. Used by the author for fixing the nerve cells of the spinal ganglia.

Orth's Fluid (Formalin Müller's Fluid).—Potassium dichromate, 2.5 gm.; sodium sulphate, 1 gm.; water, 100 c.c.; formalin, 10 c.c. This fluid must be freshly prepared each time as it soon decomposes. When it is used in large quantities the salts may be made up into solution and the formalin added at the time of using; or a solution of the salts may be made of double strength and diluted with an equal volume of twenty-per-cent. formalin at the time of using.

Small pieces of tissue are fixed in this fluid for from twelve to twenty-four hours; then washed in running water for from six to twelve hours; and finally placed in eighty-per-cent. alcohol.

This fluid is the best general fixing fluid we have.

Methods of Decalcification.—Specimens to be decalcified should be reduced to pieces about 2 mm. in thickness. This can be done with a fine saw. They are then thoroughly hardened and placed in the decalcifying fluid. When they are decalcified, which may be tested by passing a needle into the tissue, they are thoroughly washed in running water until all the acid is removed; they are then hardened in alcohol.

Hydric Chloride.—One part of strong hydric chloride is mixed with ten parts of water, and ten per cent. of sodium chloride is added. Without the addition of the latter the acid will cause some tissues to swell. The specimen of bone is placed in a large quantity of this fluid, and a little fresh acid added day by day until the bone has become soft. Then it is washed in water until all traces of acid are removed, and preserved in alcohol.

Hydric Chloride and Palladium Chloride.—Waldeyer employs a one-thousandth-per-cent. solution of palladium chloride with one-tenth of its volume of hydric chloride for softening the cochlea. Small pieces of bone are placed in this fluid for twenty-four hours. If they are not softened at the end of this time the fluid is renewed, and they are allowed to remain another twenty-four hours, when, as a rule, they will be found completely softened. The specimens are then washed in alcohol, which is renewed at the end of twenty-four hours. This fluid does not cause the tissues to swell, nor does it interfere with the staining.

V. Ebner recommends a two-per-cent. solution of hydric chloride in a half saturated solution of sodium chloride. This fluid is slow in its action and should be changed daily until the specimens are thoroughly decalcified. The specimens are then washed in a half saturated solution of sodium chloride, to which a few drops of ammonium hydrate are added, until the reaction of the bone becomes neutral.

Hydric Chloride and Alcohol.—Hydric chloride, 2.5 c.c.; alcohol, 500 c.c.; water, 100 c.c.; sodium chloride, 2.5 gm.

Or hydric chloride, 1 to 5 c.c.; alcohol, 70 c.c.; water, 30 c.c.; sodium chloride, 0.5 gm.

Hydric Nitrate.—This acid is highly recommended by Busch. He employs a ten-per-cent. solution for adult bones and a one-per-cent. solution for fœtal bones. Fresh bones are placed for three days in ninety-five-per-cent. alcohol; then placed in the nitric-acid solution, which is changed daily until decalcification is complete. This requires from eight to ten days. The bones are then washed in runing water for two hours, and finally placed in ninety-five-per-cent. alcohol, which is renewed at the end of three days.

Fœtal bones are first placed in a mixture of one-per-cent. potassium bichromate and one-tenth per cent. of chromic acid for one or two days; then decalcified in one-per-cent. hydric nitrate. When thoroughly decalcified they are washed in water and preserved in alcohol.

Sections of bone treated by this method stain well with eosin, but staining with hæmatoxylin is seldom successful.

Hydric Nitrate and Alcohol.—Mayer uses a five-per-cent. solution of hydric nitrate in ninety-per-cent. alcohol; Thoma 5 parts of strong alcohol and 1 part of hydric nitrate, renewing the fluid daily until the specimens are decalcified.

Phloroglucin and Hydric Nitrate (Haug).—Phloroglucin, 1 gm.; hydric nitrate, 10 c.c. The phloroglucin is placed in a porcelain dish and the hydric nitrate added drop by drop; it should be warmed carefully, as the action of the acid on the phloroglucin is very energetic. When all the acid has been added, the solution is diluted with 100 c.c. of distilled water. This should give a clear ruby-red colored fluid. Then there must be added 10 c.c. of hydric nitrate, the solution being afterward brought up to 300 c.c. by the addition of water.

The phloroglucin acts as a protector to the organic constituents and has no decalcifying action.

The action of this fluid is very rapid. Fetal and young bones become soft in half an hour; older bones, like pieces of the femur, require from four to five hours.

After decalcification the specimens are washed in running water for two or three days.

This solution may be made with hydric chloride instead of hydric nitrate, 30 c.c. of the HCl being used.

A slower acting fluid can be made as follows: Phloroglucin, 1 gm.; hydric nitrate, 5 c.c.; alcohol, 70 c.c.; water, 30 c.c.

These solutions should be made fresh as they do not keep well.

Ferri's Solution.—Dissolve 1 gm. of phloroglucin, by the aid of heat, in a mixture of 100 c.c. of water and 10 c.c. of hydric chloride; when cold add 200 c.c. of seventy-per-cent. alcohol.

Picric Acid.—This is used in saturated aqueous solution. It is slow in its action. The specimen should be small, and be suspended in a large quantity of the fluid. The latter must be kept in a saturated condition by the addition of fresh crystals of the acid and frequent agitation.

Schmol recommends the following mixtures: A. Formalin, 100 c.c.; hydric nitrate, 20 c.c. B. Müller's fluid, 100 c.c.; hydric nitrate, 3 c.c.

Trichloracetic Acid.—This acid has been recommended for decalcification. It acts slowly, and is used in five-per-cent. solutions.

Methods of Dissociation.—*Mechanical.*—*Scraping and Teasing.*—Which of these methods is to be employed will depend upon the nature of the tissue. Epithelium can be easily scraped off in large flakes by a knife, while fibrous parts must be teased apart with needles. Scraping is performed as follows: A small bit of the tissue is placed on a slide, with the epithelial surface uppermost, one end fixed with a needle, and the surface lightly scraped with the blade of a scalpel, the result of the scraping diffused in a drop of water, salt solution, or glycerin on a slide, and examined.

For teasing we employ needles mounted in handles. Various forms of the latter are supplied by instrument-makers, but a needle forced into the end of an ordinary pen holder will answer every purpose. In order to tease a specimen successfully, it is necessary to have some idea of its structure, whether its elements are arranged in parallel fibres or interlaced. In tissues arranged in parallel fibres, the needles are applied to one extremity and the specimen is torn into two parts; one of these is selected and the operation is repeated until it is impossible to separate the fibres any more. In other tissues a small bit is fixed by one needle, and with the other, commencing at one edge, the teasing is carried on in a deliberate manner until the tissue is reduced to the required degree of fineness. The operation of teasing is performed on a slide in a small drop of fluid. Unstained material is placed on a black background, stained material on a white background.

Brushing.—This operation is performed under water by gently brushing the surface with a camel's-hair brush.

Shaking.—Thin sections of tissue are shaken in a test-tube with a suitable fluid, then the contents of the tube are poured into a dish of water, the sections being floated on a slide.

Compression.—By making pressure on the cover-glass, especially after maceration of the specimen, one is often able to separate the elements. This pressure can be made with the handle of a teasing needle, but it is apt to be unequal, and there is danger of breaking the cover and thus destroying the specimen. It is better to use an instrument called a compressorium, constructed especially for this purpose. In Fig. 2670 is shown one form, invented by H. Jung, of Darmstadt.

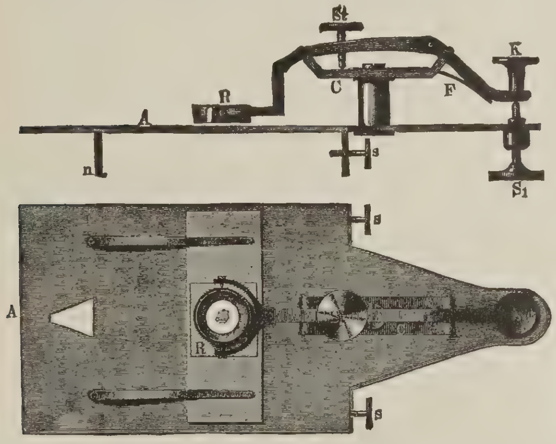

FIG. 2670.—Jung's Compressorium.

The plate *A* is attached to the stage of the microscope by the catch *n* and the two screws *s*, *s*. On this plate is a double lever, one arm of which has a movable ring, *R*, and adjusting screw, *St*, and the knob *K*. The two levers are so connected with the bent piece *C* that when *K* is pressed down the ring *R* is also pressed toward the stage plate. Conversely, an upward movement of the knob, produced by the spring *F*, raises the ring. For use as a compressor the screw S_1 is loosened, and *St* screwed down until the desired degree of pressure is obtained. This apparatus can also be employed for another useful purpose, viz., beating. The process of beating is often resorted to for the purpose of isolating cells, tissue, etc. In using the instrument for this purpose the screw *St* is so adjusted that the ring *R* lies close to a large and thick cover-glass covering the specimen, and S_1 is turned so that the lever can move but slightly. By quick and continuous movement of the lever, and the changing pressure on the cover-glass thus produced, tissues (after maceration) can be easily dissociated. When the cells are isolated they can be made, by a slower movement of the lever, to move about in all directions, so that they can be observed from all sides.

Interstitial Injection, or Artificial Œdema.—A hypodermic syringe is filled with salt solution or a warm solution of gelatin, the needle is inserted into the tissue—*e.g.*, the subcutaneous tissue of a freshly turned-up flap of skin—and the fluid is forced out. The fluid does not immediately diffuse itself, but forms a bulla covered with a thin film of tissue. A bit of this film is snipped off with scissors and examined. If gelatin be used, it soon solidifies, when thin sections are made with a razor.

Chemical Dissociation.—By submitting tissues to the action of different chemical solutions certain parts become dissolved or softened, while others remain unaltered. Consequently certain elements can be easily isolated by one of the mechanical methods.

The reagents used for this purpose are as follows:

Dilute Alcohol, "Alcohol au tiers" of Ranvier.—Alcohol of ninety-per-cent. strength is diluted with two parts of water. Bits of tissue are placed in this fluid for twenty-four hours; if at the end of this time the tissue is not sufficiently softened, the fluid is renewed and the action continued for twenty-four hours longer. Recommended highly by Ranvier for isolating epithelial cells.

Osmic Acid of the strength of one-tenth per cent. is recommended by Rindfleisch for the cerebral cortex. Small pieces of the cortex are placed in a considerable quantity of the fluid for a week or ten days, then in glycerin.

Chromic Acid is employed in the strength of two to three parts to one thousand of water. Recommended especially for nerve tissue and smooth muscle. The amount of fluid should be ten times greater than the piece of tissue. After macerating for twenty-four hours, the tissues are easily dissociated.

Potassium Dichromate is employed in the same strength as chromic acid, its action being similar. Müller's fluid, diluted with an equal volume of water, is also employed as a macerating fluid. Its action requires from twenty-four hours to a week.

Potassium Hydrate.—Used in twenty- to forty-per-cent. solutions in water. It acts very quickly on fresh tissues, and is used mostly for isolating the cells of nails, hairs, and epidermis. Sodium hydrate may be used in its place, but in more dilute solutions. Preparations made by this method cannot be permanently preserved.

For isolating histological elements S. H. Gage uses a thirty- to fifty-per-cent. solution of potassium hydrate. Perfectly fresh tissue is used. Pieces about half a cubic centimetre in size are placed in a large amount of the potassium hydrate solution until they can be easily shaken apart. The potash solution is then poured off and replaced by a sixty-per-cent. solution of potassium acetate containing one per cent. of hydric acetate. After a short time the tissue is washed in water; then stained in alum carmine for twenty-four hours; then washed in water and preserved in glycerin.

Sodium Chloride.—Used in ten-per-cent. solution in water for isolating white fibrous tissue. It requires from two to three days for its action.

Hydric Nitrate.—Used in twenty-per-cent. solution for muscle fibres. After being acted upon for twenty-four hours, the fibres are easily isolated by shaking the specimen in a test-tube with water. Schwalbe uses a twenty-per-cent. solution for isolating nerve fibres for measurement. He macerates the nerve trunk in the above solution at a temperature of 40° C. for twenty-four hours, and then washes in water. The fibres retain their normal diameter, but become very brittle.

Hydric Nitrate and Potassium Chlorate.—A piece of striated muscle is buried in crystals of potassium chlorate placed in the bottom of a vessel, and four times the volume of the crystals of hydric nitrate is poured on and allowed to act half an hour; the muscle is then shaken in a test-tube with water, when it will break up into isolated fibres.

Hydric Chloride is used mixed with an equal volume of alcohol for isolating the tubules of the kidney. A small bit of fresh kidney is placed in this mixture for twelve hours, then soaked in water for a few hours to remove the acid, and preserved in glycerin. The acid partially dissolves the intertubular tissue, so that by very careful teasing the tubules can be isolated. It is also employed in the strength of 1 to 250 of water for cleaving striated muscle tissue into discs.

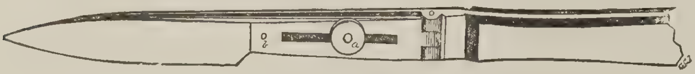

Fig. 2671.—Valentine's Knife.

Artificial Digestion.—For the purpose of artificial digestion we make use of either pepsin or trypsin.

Brücke's Pepsin Fluid. — Glycerin extract of pig's stomach, 1 part; 0.2 per cent. HCl, 3 parts; thymol, a few crystals.

Kuskow's Pepsin Fluid.—Pepsin, 1 gm. is dissolved in 200 c.c. of a three-per-cent. solution of oxalic acid. The fluid should be prepared fresh each time.

Pancreatic fluid can also be made by dissolving six to seven per cent. of trypsin in water containing one per cent. of salicylic acid.

Schiefferdecker's Pancreatin Fluid.—A saturated solution of Pancreatinum siccum (Witte) is made in cold distilled water and filtered.

Pieces of tissue may be first digested in these fluids and then sections cut, or the sections may be first cut and then submitted to the action of the fluids. The digestive process is to be carried on at a temperature of from 37° to 38° C., either in an incubator or on a warm stage on the microscope.

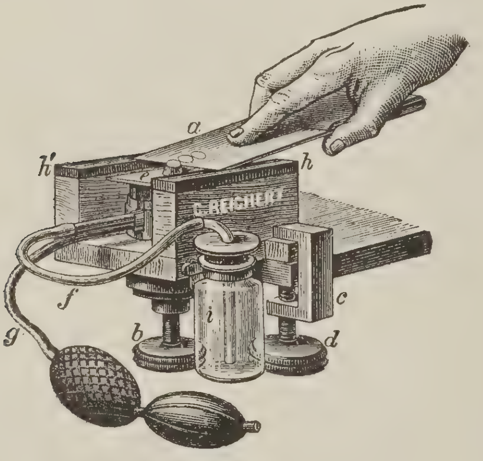

Fig. 2672.—Ether-Freezing Microtome.

Pepsin quickly dissolves connective tissue, muscle, most cellular elements, etc., but not elastic tissue or nerve fibres. Trypsin, on the other hand, dissolves elastic fibres and neuroglia, while connective tissue is not acted upon.

Methods of Making Sections.—*Sections of Hard Tissues.*—Sections of undecalcified bone, teeth, etc., are made by cutting thin plates by means of a fine saw or an iron disc, on a lathe fed with flour of emery and water. These plates are then ground on a metal plate charged with flour of emery and water until transparent; they are then polished on a Turkey hone, washed in water, and dried in the air.

Sections of Fresh Tissue.—For making sections of fresh tissue Valentine's double knife (Fig. 2671) may be used, though the sections are generally too thick. This knife consists of two parallel blades attached to each other at their lower end by a hinge. At *a* is a screw sliding in a slot, by means of which the blades are approximated. For use, the knife is forced into the organ; cutting a thin slice which remains enclosed between the blades. The knife is then withdrawn and the blades are opened by sliding back the screw *a;* the slice of tissue adhering to one of the blades is floated off in salt solution.

At the present time one of the numerous forms of freezing microtomes is used for making frozen sections of fresh tissues. For freezing the tissue ether, rhigolene, or compressed carbon dioxide is used. Compressed carbon dioxide can now be obtained in steel cylinders, and is used to a considerable extent in place of ether. One of the usual forms of ether-freezing microtomes is shown in Fig. 2672. The specimen to be frozen is placed on the metal plate *e*, and is frozen by a spray of ether delivered on the under side of the plate by the spray tubes passing through its side. The ether is placed in the bottle *i*. The air is compressed by the double bulbs and conveyed to the spray tubes through the tube *g;* the ether through the tube *f*. The knife *a* is broad and has a chisel edge; it slides on the glass ways *h'h*. The surface of specimen plate is raised by the micrometer screw *b*.

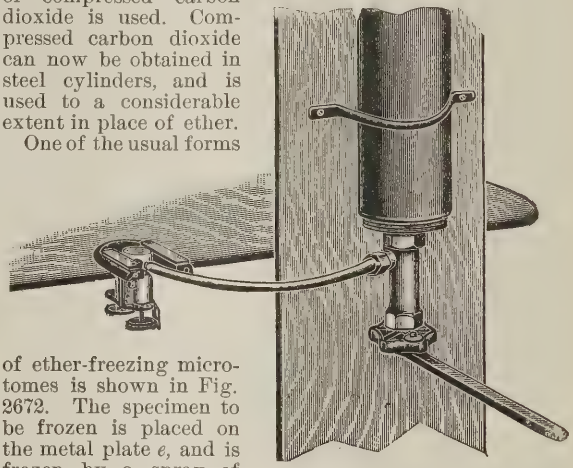

Fig. 2673.—Carbon-dioxide Cylinder Connected with Freezing Microtome.

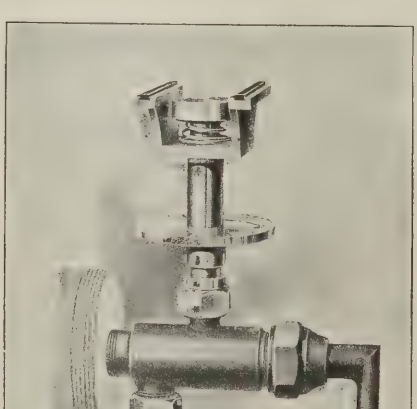

Fig. 2674.—Bardeen's Microtome.

In Fig. 2673 is shown one of the arrangements for using carbon dioxide for freezing. The steel cylinder is fastened to an upright plank so that its valve end comes on or about the level of the table. A thick rubber tube for conveying the gas passes to the microtome. The valve is opened by a long lever allowing the flow of gas to be easily controlled.

Professor Bardeen's freezing microtome is shown in Fig. 2674. This microtome is very simple in construction and is attached directly to the outlet tube of the steel cylinder The improvements introduced by Professor Bardeen, in both the microtome and the valvular arrangements of the cylinder, have resulted in a great saving of the carbon dioxide.

Specimens from which frozen sections are to be made should not be over 4 mm. thick. The freezing should be done slowly, and they should not be allowed to become too hard.

Several methods are now in use whereby sections of fresh tissue may be cut, stained, and mounted in a very short time. One of the earlier methods, that of Cullen (*Johns Hopkins Hospital Bulletin*, April, 1895, and May, 1897), has been modified and improved. Two of the principal modifications are as follows:

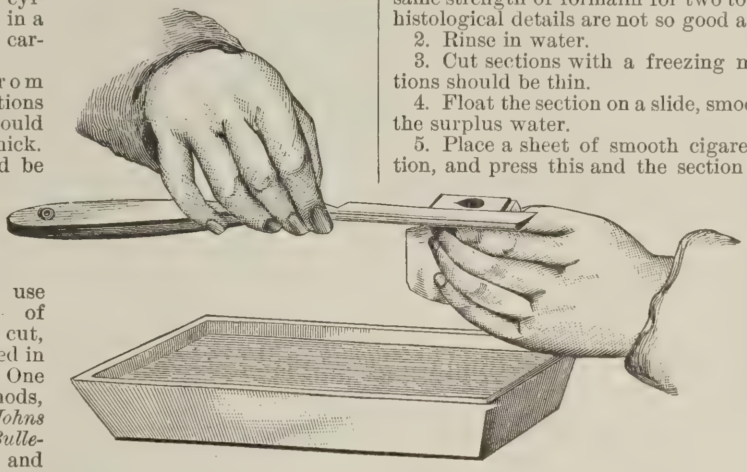

FIG. 2675.—Section-cutting.

Hodenpyl's Modification.—Any form of freezing microtome may be used. The technique is as follows:

1. Sections may be cut from perfectly fresh material, or from material which has been previously hardened one or two hours or longer in ten-per-cent. formalin. (It is convenient to drop bits of tissue into ten-per-cent. formalin at the time of the operation or during the post-mortem examination. By the time they reach the laboratory they are usually sufficiently impregnated to be cut and stained.)

2. Tissues already hardened in formalin should be soaked in water for a minute or two to remove the formalin before cutting.

3. Sections as they are cut may be dropped directly into the albumin solution, where they remain until needed. A solution of albumin which has been found to answer the purpose is prepared by adding to 50 c.c. by volume of egg albumen 150 c.c. of distilled water and sufficient of a solution (usually about 50 c.c.) of salicylic acid (saturated), which has been rendered slightly alkaline with lithium carbonate, completely to dissolve the albumen. The solution may be kept unchanged several weeks by adding a little gum camphor.

4. Unhardened sections should be placed in five-per-cent. formalin for from three to five minutes, after which they are soaked in the albumin solution for two or three minutes.

5. The sections are floated on cover-glasses, the excess of fluid being removed with filter paper when necessary. The sections are then blotted evenly, care being taken not to use pressure enough to cause them to bear the imprint of the cloth. (The best blotting material seems to be washed cheesecloth used in several layers. The use of filter paper, towels, muslin handkerchiefs, etc., for this purpose has not been satisfactory.)

6. The section must then be transferred immediately to alcohol, alcohol and ether (equal parts), osmic acid, or mercuric chloride, etc., in order to coagulate the albumin and to fix the section and complete the hardening.

7. Sections may be stained on the cover slip in various ways. For ordinary diagnostic work staining with hæmatoxylin and eosin answers well. The following is the method of procedure. (*a*) Stain for from two to five minutes in hæmatoxylin. (*b*) Decolorize by passing rapidly through acid alcohol—hydric chloride, 1 part; eighty-per-cent. alcohol, 99 parts. (*c*) Wash thoroughly in water. (*d*) Dehydrate and stain in eosin alcohol. (*e*) Clear in oil of origanum, oil of cloves, xylol, etc. (*f*) Mount in balsam.

Wright's Modification.—1. Place the fresh specimen in ten-per-cent. solution of formalin for about two hours. If time does not allow of this, boil the specimen in the same strength of formalin for two to three minutes. The histological details are not so good after boiling.

2. Rinse in water.

3. Cut sections with a freezing microtome. The sections should be thin.

4. Float the section on a slide, smoothe out, and remove the surplus water.

5. Place a sheet of smooth cigarette-paper on the section, and press this and the section down with a pad of soft, smooth filter paper, the face of which has been moistened with a few drops of ninety-five-per-cent. alcohol. Remove the filter paper and carefully strip off the cigarette paper, leaving the section adhering to the slide.

6. Flood the section, adhering to the slide, with absolute alcohol; after about thirty seconds drain off the alcohol.

7. Flow over the section and the adjacent surface of the slide a *thin* solution of celloidin; drain off immediately.

8. Flood the slide with ninety-five-per-cent. alcohol, and immediately place the slide for ten seconds in water. This hardens the celloidin film and prevents the section from curling.

9. Stain with hæmatoxylin or any combination of stains.

10. Dehydrate in ninety-seven-per-cent. alcohol.

11. Clear in oil of origanum, and mount in balsam.

Sections of Hardened Tissue.—Sections of hardened tissue may be made by free-hand cutting, or by the microtome. For free-hand cutting, the first requisite is a good razor or knife. An ordinary hollow-ground razor, with the lower side ground flat, will answer; but if one practises free-hand cutting to any extent, it is better to be provided with a larger and heavier one.

The section cutting is performed as follows: A shallow dish is partially filled with alcohol, with which the specimen and razor blade are to be constantly flooded, the blade being dipped into the alcohol. The specimen is held firmly between the fingers and thumb of the left hand (Fig. 2675), and the razor lightly with the right, the handle resting on the fingers, the thumb being used for changing the direction of the edge of the razor. The section is cut by drawing the razor blade diagonally

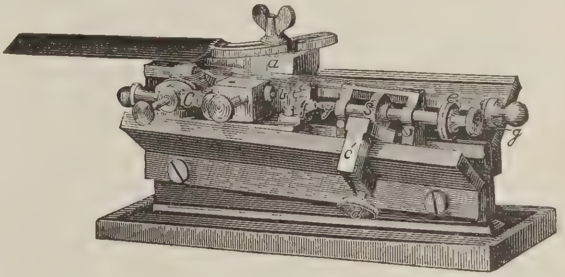

FIG. 2676.—Thoma's Sliding Microtome.

through the specimen, from heel to point, and then floated off into a dish of alcohol. After cutting every third or fourth section the razor should be stropped, so as to keep the edge in the best possible condition.

Microtomes.—Thoma's sliding microtome (Fig. 2676) consists of a stand of cast iron, on which slide two carriers. The section knife is attached to one of these, *a*, which slides horizontally. The other, *b*, holds the specimen to be cut, and moves on an inclined plane.

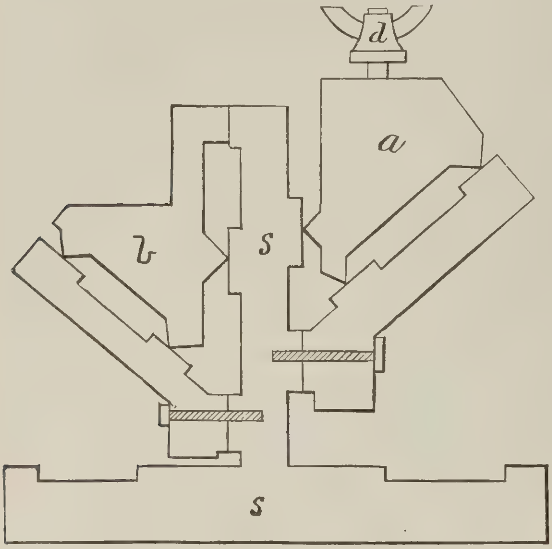

FIG. 2677.—Vertical Section, Thoma's Microtome.

Professor Thoma found that a carrier moving on five points between two plane surfaces, will slide without difficulty between these planes, even if they are not absolutely geometrical planes, or if the angle included is not everywhere the same. Such a carrier will always take the same course, and consequently the knife will cut a series of perfectly parallel sections through an object which is successively raised to a higher plane after each cut.

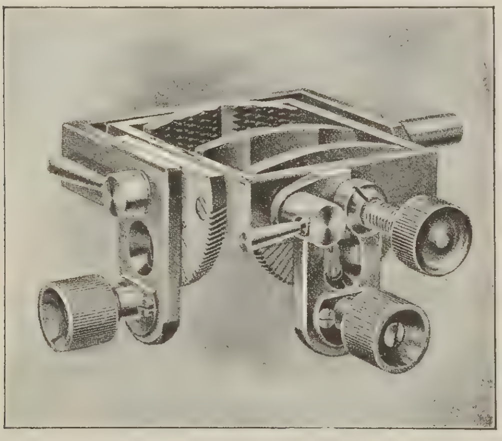

FIG. 2678.—Naple's Universal Clamp.

A cross-section of the instrument is shown in Fig. 2677. On the lower surface of the carrier *a* are shown three points, which give the geometrical projection of the five points of the carrier.

The inclination of the plane upon which the carrier *b* (Figs. 2676, 2677) slides is one in twenty; consequently, if the carrier *b* is moved 1 mm. on this plane it will raise the surface of the specimen .05 mm. A scale of millimetres, *e*, with a vernier *e'* (Fig. 2676), allows the operations to be easily regulated, and will be found sufficient for sections of 0.015 mm. in thickness. When sections of greater delicacy are required the micrometer screw *g*, *g* (Fig. 2676) is to be used, as it allows of the greatest exactitude in the management of the carrier *b*. The carrier *c'* slides on the same plane as the carrier *b*. In all positions of the latter it is possible to bring the point of the micrometer screw *g*, *g* in contact with the polished plate of agate, *f*, fixed on *b*. When in this position, *c'* should be firmly fixed to the stand of the microtome by the screw *d*. Every revolution of the micrometer screw *g*, *g* will then push the carrier *b* 0.3 mm., giving a thickness of section equal to 0.015 mm. The periphery of the drum, *s*, attached to the screw *g*, *g* is divided into fifteen equal parts; consequently, each division corresponds to a thickness of section equivalent to 0.001 mm. The first sections cut by this instrument have been 0.002 mm. in thickness.

When the microtome is used, it is placed on a table before the operator, the slides are freely oiled, and the surface of the knife is flooded with alcohol. The specimen fixed to a block is fastened in the clamp.

The Naple clamp (Fig. 2678) is the one now generally used and can be adapted to most of the microtomes. It is movable on two axes, one parallel to the long axis of the microtome, the other at right angles to it. This allows of the adjustment of the surface of the specimen to the plane through which the knife passes in cutting. The clamp is then fixed in a position as near the knife carrier *a* as possible.

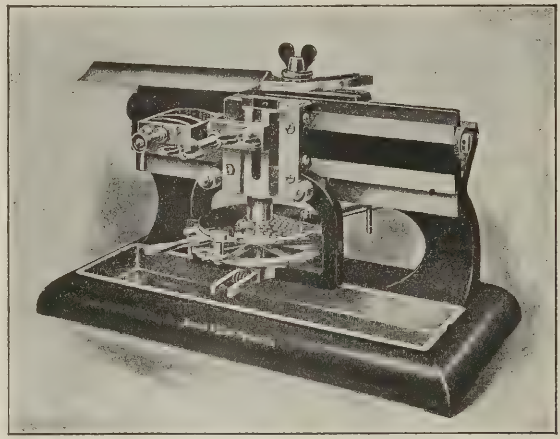

FIG. 2679.—New Form of Sliding Microtome with Automatic Feed Attachment.

The knife is so adjusted that it will be drawn obliquely through the specimen from heel to point. The sections, after being cut, are removed from the knife with a camel's-hair brush, and placed in a dish of alcohol.

In cutting sections of hard substances, such as the aorta and cartilage, it often happens that the sections, instead of being even, are thicker at one point than at another; or that the sections are striped, their thickness varying at different points. Professor Thoma has found that this is due to the fact that hard substances bend the edge of the ordinary knife. For preventing this he has introduced knives with stronger edges and shorter blades.

In Fig. 2679 is shown one of the newer forms of sliding microtomes with automatic feed attachment. It is adapted either for celloidin or paraffin cutting. The object clamp remains fixed during the cutting. The knife is clamped to the knife carrier, a triangular block, which slides on horizontal runways.

The automatic feed attached to the micrometer screw is operated by the motion of the knife carrier and is so adjusted that sections from 2 to 60 μ in thickness may be cut.

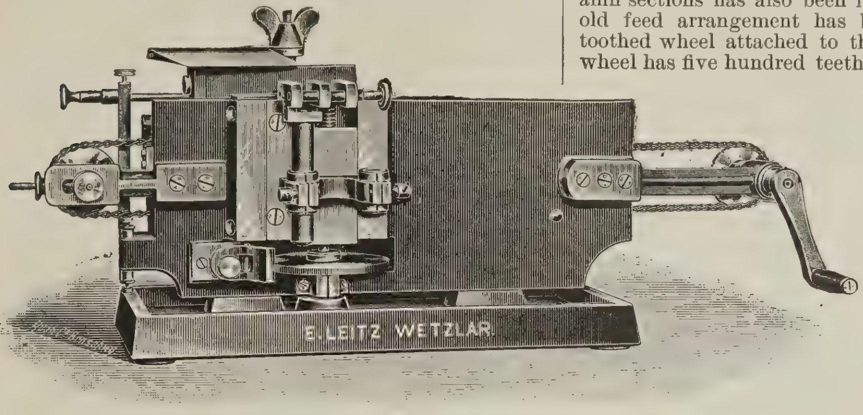

FIG. 2680.—Large Sliding Automatic Microtome.

A larger form of automatic sliding microtome is shown in Fig. 2680. The knife carrier runs on a horizontal track and is moved by a chain attached to either end of it. This chain passes around two wheels, one of which is turned by a crank attached to it, causing a uniform sliding motion.

The specimen clamp is raised vertically by a micrometer screw to which is attached a large, toothed, circular disc, each tooth of which equals an elevation of 0.0025 mm.

The automatic feed is so arranged that each time the knife carrier reaches the left-hand end of the tract it strikes a lever which causes the circular disc attached to the micrometer screw to revolve. The lever being adjustable, it can be made to cause the disc to move any number of teeth from one to ten with each movement of the knife carrier, thus giving a thickness of section from 0.0025 mm. to 0.025 mm. in thickness.

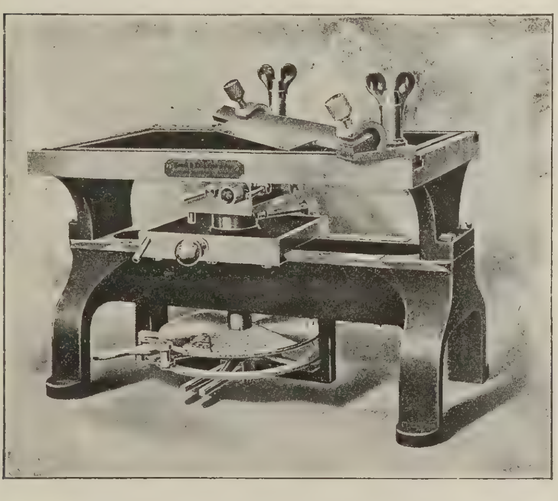

FIG. 2681.—Minot Automatic Precision Microtome.

The "Precision" microtome of Minot (Fig. 2681) is a departure from the usual form of sliding microtome in that the knife is fixed and the object clamp is on a sliding carrier.

The knife is clamped to the frame of the microtome, and the object clamp carrier runs on slides under the knife. There is an automatic feed attachment that may be regulated so that sections from 1 to 60 μ in thickness may be cut. This microtome may be used for celloidin or paraffin preparations.

The older form of Minot's rotary microtome for paraffin sections has also been improved (Fig. 2682). The old feed arrangement has been replaced by a large-toothed wheel attached to the micrometer screw. This wheel has five hundred teeth, and the micrometer screw has a pitch of 0.5 mm., so that each tooth of the wheel equals a feed of 1 μ. The feed of the micrometer screw is controlled by an adjustable cam, so that the thickness of section may be made to vary from 1 to 25 μ.

An adjustable carrier (Fig. 2683) for serial ribbons may be attached.

Microtome Knives.—The usual form of microtome knife is shown in Fig. 2684. Its upper surface is concave, its under one flat. Its cutting edge is of a double chisel form, and must be perfectly straight. The knife should be heavy and its length adapted to the size of the microtome used.

A knife for cutting paraffin should be heavier than one used for celloidin.

In order to obtain good sections the cutting edge of he knife must be kept in the best possible condition. This is accomplished by stropping the knife frequently and honing it occasionally.

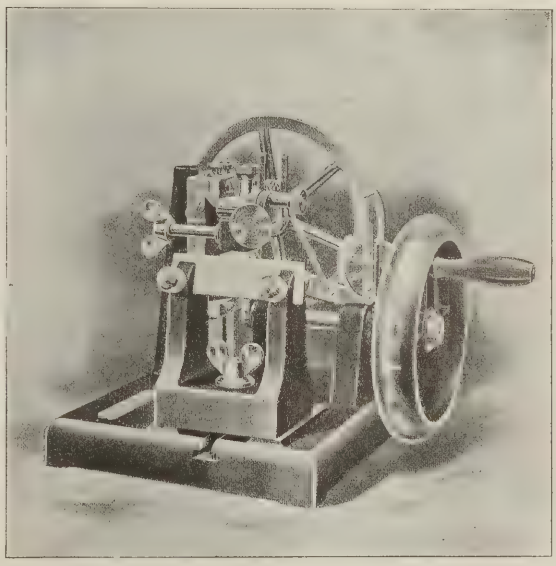

FIG. 2682.—Improved Rotary Microtome of Minot.

For honing, a yellow Belgian hone of large size is to be used. Its surface is thoroughly covered with a lather made with a pure soap and water. This lather is better than oil as it keeps the pores open and gives a better grinding surface. In honing, one of the backs (Fig. 2684) is fastened to the knife. This is for the purpose of keeping the angle of the edge of the knife constant. The knife is first sharpened on its concave side, then turned and sharpened on the flat side. The pressure on the knife should be light; it should be drawn across the hone from heel to toe, the edge being drawn against the surface of the hone. The movements are illustrated in Fig. 2685.

For stropping the best form of strop is that known as the bow strop (Fig. 2686). The movements of the knife are the reverse of those of honing, and are shown in Fig. 2686. After use the knife should be carefully dried with a soft cloth.

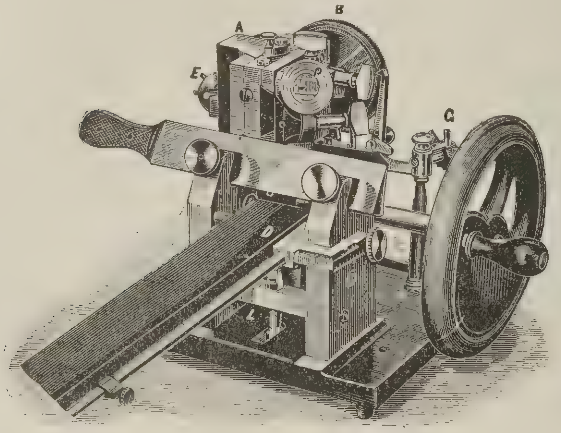

FIG. 2683.—Showing Carrier for Ribbon Sections Attached to Minot's Rotary Microtome (Old Form).

After the sections are cut they are removed from the microtome knife with a camel's-hair brush and placed in a dish of fluid. For sections of fresh tissue and frozen sections, salt solution should be used, the sections being submerged in it; for sections of alcoholic specimens, alcohol or water may be used.

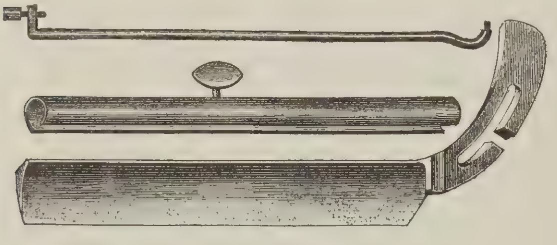

FIG. 2684.—Microtome Knife with Two Forms of Backs used in Honing and Stropping.

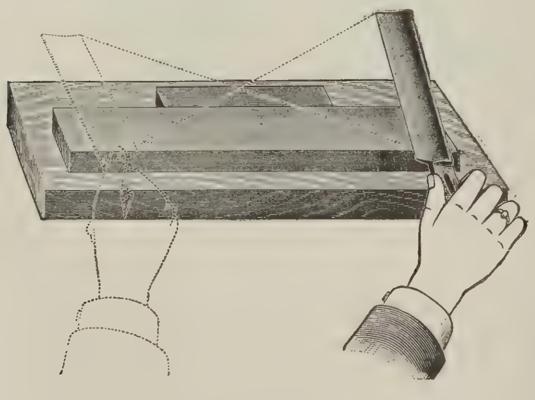

FIG. 2685.—Showing the Movements of the Knife in the Process of Honing.

In the further manipulation of the sections great care must be taken or they will be destroyed. For transferring them from the different reagents, stains, etc., a needle, camel's-hair brush, or nickel-plated steel spatula (Fig. 2687) must be used. In the majority of cases the latter instrument will be found most convenient. It is placed cautiously under the section floating in the fluid, gently raises it, and transfers it to a second vessel of fluid or to a slide.

When sections are transferred from alcohol to water, they spin about in a lively manner and finally spread out into thin laminæ. This is caused by the rapid diffusion of the alcohol.

Sections can be preserved indefinitely in eighty- to eighty-five-per-cent. alcohol.

Serial Section Cutting.—The preparations to be cut are to be embedded in paraffin. The melting point of this must have a certain relation to the laboratory temperature. A laboratory temperature of 17° C. requires a paraffin melting at 45° C. At a temperature of 15° C. this paraffin would be too hard. At 22° C. a paraffin melting at 48° C. will be required.

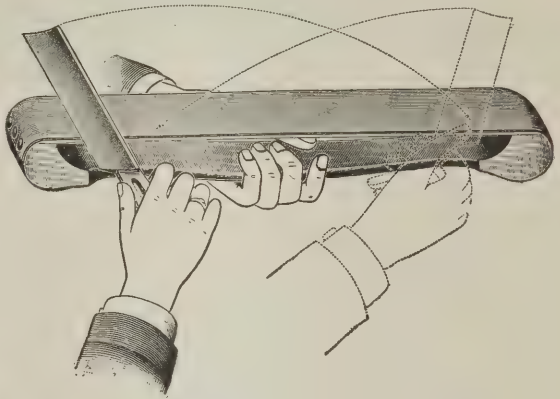

FIG. 2686.—The Bow Strop, and the Mode of Stropping.

After impregnation the specimens are embedded by one of the methods described under paraffin embedding.

The block of paraffin should be pared down close to the specimen, and should be cut so as to present a straight edge parallel to the edge of the knife, and the opposite edge parallel to this. If this precaution is not taken the sections will not adhere, and will not pass off in a straight line.

The sections can be cut on any sliding microtome, provided the knife be set square. Several special microtomes have been constructed for this kind of section cutting, viz., Caldwell's automatic microtome, Cambridge rocking microtome, and Minot's automatic wheel microtome.

The sections are fixed upon a slide by one of the following methods:

Water Method: The ribbons of sections are cut to proper lengths and floated on warm water, warm enough to soften the paraffin, but not to melt it, when the sections will flatten out. They are then floated on a slide and arranged in position. The slide is then drained and allowed to become perfectly dry. To hasten the drying the slides may be placed in a water-oven at a temperature of 40° C. The paraffin must not be allowed to melt until the sections are perfectly dry. When perfectly dry the sections adhere to the slide, when the paraffin is melted and washed off with xylol.

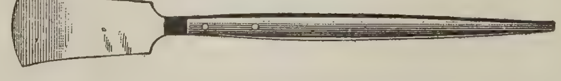

FIG. 2687.—Spatula.

Mayer's Method: Paint a mixture of equal parts of filtered white of egg and glycerin (and a few drops of carbolic acid as a preservative) on a slide with a camel's-hair brush, and arrange the sections with this; then warm the slide on a water bath for a few moments until the paraffin is melted. As the paraffin in the sections melts it carries the albumen away from them. The paraffin is next to be dissolved out with turpentine or xylol, the latter removed with alcohol, and the sections stained.

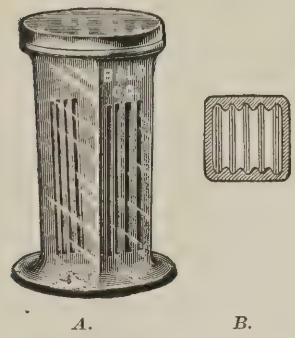

FIG. 2688.—Staining Jar for Serial Sections Mounted on Slides.

Schällibaum's Method: Mix one part of collodion with three or four parts of oil of cloves and shake well. Spread this solution in a thin layer, with a brush, on a slide; arrange the sections and evaporate them by gentle heat on a water bath. Then dissolve out the paraffin with xylol. The sections thus fixed may be stained in the usual way and mounted in balsam or glycerin.

Serial Sections of Celloidin-Embedded Specimens. — 1. Prepare a series of glass plates; coat these with a thin layer of celloidin, as a photographer makes a moist plate, and allow them to dry.

2. Make sections and arrange ribbon-wise on strips of transparent porous paper, which should be double the width of the sections. Keep the strips, with the sections on them, moist by placing them on blotting paper in a dish with alcohol.

3. Transfer the sections to the celloidin-coated plate. Lay the strips, section side down, upon the glass plates, press them softly, and peel off the paper; remove all superfluous fluid with filter paper, taking care not to dry the sections.

4. Cover the sections with a thin layer of celloidin. When dry, the celloidin may be marked with a brush dipped in methyl blue, so that the series may be recognized.

5. Immerse the plates in water, and the celloidin will peel off from them, and we shall have the sections enclosed between two layers of celloidin, allowing them to be handled like a rag.

6. The celloidin plate may be cut up into as many pieces as there are sections, or it may be stained uncut and mounted in the usual way.

Staining.—The tissues may be stained *in toto* before being embedded in paraffin or after they are fixed to the slide. The latter is the method generally adopted, as a greater variety of stains may be employed.

In Fig. 2788, *A*, is shown a staining jar for holding ten slides. In *B* is shown a transverse section of the jar. The sides of the jar are grooved, the width of the groove being such that two slides, back to back, may be placed in it. These jars may also be used for dissolving out the paraffin, dehydrating, clearing, etc.

Born's Method of Reconstructing Objects from Microscopical Sections.—By the aid of a camera the outlines of the sections are transferred to wax plates, which are then cut out so as to correspond in outlines as well as in dimensions to the sections equally magnified in all three directions.

He makes three rectangular boxes of tin, 270 mm. × 230 mm. × 2.5 mm. The sections should be 0.04 mm. thick (never thinner than 0.02).

If we wish to construct a model of a specimen from sections $\frac{1}{30}$ mm. thick and magnified sixty diameters, the wax plates must be 2 mm. thick. Such a plate made in a box of the above dimensions contains 62.1 mm.; and its volume will be 124.2 mm. The specific gravity of beeswax is 0.96 to 0.97. It is melted with a small quantity of turpentine, which reduces its specific gravity to about 0.95; and the weight required to make one plate of the above size is, in round numbers, 118 gm. This quantity of wax is weighed out and melted. The tin box is filled 1.5 cm. deep with boiling water and the melted wax poured upon it. As soon as the plate has begun to stiffen, and while it is still soft, it should be cut away from the edges of the box, and, when the water has become tepid, removed to a flat support to stiffen.

For drawing the outlines of the section a piece of blue paper is placed, colored side down, upon the wax plate, and over this an ordinary sheet of drawing paper. The outlines are drawn on the latter, by the aid of a camera, and at the same time blue lines are traced on the wax. Then, with a small knife, the wax is cut out, the outlines being followed, the plates are placed together in the proper order, and fastened by passing the warm spatula along the edges.

METHODS OF EMBEDDING.—This process is divided into two classes: simple embedding, when the specimen, being small, cannot be held conveniently in the hand or clamped in the microtome, and is simply surrounded with an embedding mass to give it bulk; interstitial embedding, or impregnation, when the specimen is permeated with the embedding mass. The latter process is used when we have a specimen that lacks the necessary consistence for cutting (lung, etc.); or when the specimen contains cavities, the contents of which we wish to retain in their normal condition and position; or when the specimen is so brittle that it would be destroyed in the process of cutting.

Melted Masses.—Simple embedding in a melted mass (paraffin) is performed as follows: A small box is placed on a cork, and the specimen is placed in it and fixed in position by means of pins. The box is now filled with the melted mass and allowed to cool—when the pins and papers are removed, leaving the specimen enclosed in a solid block of the embedding material. Or a block of the embedding mass is taken, and a hole, a little larger than the specimen, is scooped out of one face; the specimen is washed in a melted mass of the same material and placed in the cavity, which is then filled.

The embedding boxes are made of paper. A plan which I have found very convenient is to have a series of wooden blocks, the faces of which correspond to the sizes of the boxes to be made. One of these blocks is taken, and the paper is folded over the face corresponding to the size of box wished for.

In Fig. 2689 is shown an adjustable metal embedding box for paraffin. It consists of two pieces, having the form of a carpenter's square—the long arm being 7 cm. the short 3 cm. in length, by 7 mm. high. On the outer side of the short arm is a block of metal, on the top of which is a spring (*a*, Fig. 2689), which curves over and presses against the long arm, thus holding the two pieces firmly together. The area of the box will vary with the position of the pieces. The area of the box having been fixed, it is placed on a glass plate, moistened with glycerin, and a thin layer of the melted mass poured in. When it has cooled, the specimen, which has been washed in the same material, is fixed in position and the box is filled up. When the embedding mass has cooled the box is removed, and the specimen will be found embedded in a solid block of the material.

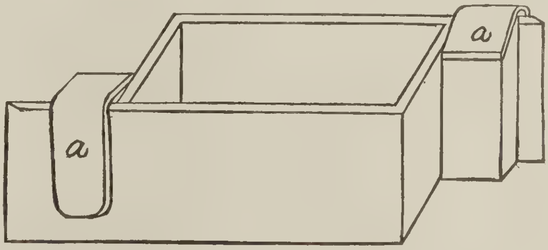

FIG. 2689.—Adjustable Embedding Box.

In manipulating with melted embedding masses, it is necessary to have a constant and comparatively low temperature, as in many cases the specimen has to be soaked in the melted mass for a considerable length of time (impregnation method). Two forms of water baths for this purpose are shown in Fig. 2690.

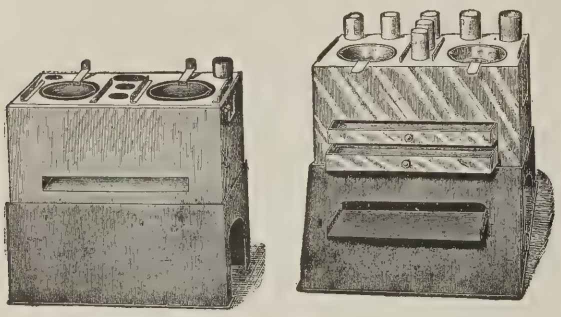

FIG. 2690.—Paraffin Water Baths.

Impregnation Embedding.—In this process the specimen is soaked in the embedding mass until it is thoroughly permeated with it. The proceeding is then like simple embedding in a melted mass.

Embedding Masses: Celloidin.—This is a pure pyroxylin, manufactured by Schering & Company, Berlin; it is free from all foreign constituents, and makes a clear solution without sediment. It is soluble in a mixture of equal volumes of alcohol and ether, and the degree of concentration can be varied to suit any particular case.

For use, a five-per-cent. solution of celloidin is made in alcohol and ether, and a portion of this is diluted with a mixture of equal parts of alcohol and ether, so as to obtain a very dilute solution. The specimen is soaked in alcohol for twelve hours; then in alcohol and ether for the same length of time; then in the dilute celloidin for at least twelve hours; then in a five-per-cent. solution for one to eight days, according to the size and density of the specimen. When the specimen has become thoroughly permeated it is to be embedded in one of the following ways:

(*a*) Cover the smooth surface of a vulcanite block with a thick layer of celloidin solution and allow it to dry. Then place the specimen, which has been soaked in celloidin, on this and cover it, layer by layer, with a solution of celloidin, allowing each layer to dry partially before applying another. When the specimen is completely covered allow it to stand in the air for half an hour, and then immerse in eighty-per-cent. alcohol for twelve hours, when it will be ready for cutting.

(*b*) Embed in a paper box in the usual way, and allow the mass to stand until a pellicle forms on the surface; then immerse in eighty-per-cent. alcohol for twenty-four hours.

Viallanes uses chloroform for hardening the celloidin. He has found that this reagent coagulates the celloidin into a mass of the consistence of wax, but very elastic and perfectly transparent. He places specimens, previously soaked in ether, in a test-tube and covers them with a solution of celloidin. As soon as a film has formed on the celloidin, the tube is filled up with anhydrous chloroform and left for two to three days, when the mass will be hardened and somewhat shrunken, so that it can be shaken out of the tube. It is then placed in fresh chloroform for six days, when it will be ready for cutting. A. B. Lee found that a few hours' immersion in the chloroform gave the required consistence, and in no case was a longer time than three days required. The celloidin frequently becomes opaque on being put into the chloroform, but becomes transparent after a time.

Oil of Cloves Celloidin (Stepknow).—Celloidin (granular form), 1.5 gm.; oil of cloves, 5 c.c.; ether, 20 c.c.: absolute alcohol, 1 c.c.

The specimen, after being dehydrated in ninety-five-per-cent. alcohol, is placed in oil of cloves for from three to six hours; then in the above solution of celloidin for six hours. Then it is embedded, preferably, in a paper box, and allowed to stand in a warm place until the celloidin thickens; then placed in eighty-per-cent. alcohol or chloroform for from one to two hours.

In case the tissues can be cut into rectangular-shaped blocks they are mounted on blocks of vulcanite and then placed in chloroform.

Sections are cut with a knife wet with alcohol, and may be stained with the usual staining agents. Some of the aniline dyes stain the celloidin intensely, and are not removed by alcohol. If sections are to be mounted in Canada balsam, they are dehydrated in ninety-five-per-cent. alcohol — absolute alcohol dissolves celloidin — cleared in oil of bergamot, sandalwood, or origanum, as oil of cedar or cloves dissolves celloidin.

Paraffin.—For embedding, paraffins of a melting point of from 45° to 55° C. are used. By mixing these in various proportions, masses may be obtained whose melting point will range between these two. Paraffin should be chosen of a melting point suitable to the temperature of the laboratory. As a rule, a laboratory temperature of 18° C. requires a paraffin whose melting point is 48° C.

The specimen to be embedded is placed, from alcohol, in chloroform until the alcohol is replaced by the latter; this takes place quickly. The specimen is then removed to a dish containing fresh chloroform and shavings of paraffin are added, so that after the evaporation of the chloroform the specimen will remain covered by the paraffin. The vessel is now placed in a water bath (see Fig. 2690), at the temperature of the melting point of the paraffin, for from one-half to one hour. The paraffin melts very quickly, and the specimen, from the evaporation of the chloroform, is bathed in a concentrated solution of paraffin in chloroform, which soon penetrates the specimen, filling up all cavities. It is essential that all the chloroform should be driven off. When this has taken place, the specimen is embedded in a box in the usual manner and allowed to cool. After cooling, the block should be trimmed and clamped in the microtome, or mounted on a cork with a little melted paraffin.

A. B. Lee recommends that the specimens be soaked in oil of cedar. This clears them rapidly, and the paraffin penetrates quickly and thoroughly.

Sections are to be cut dry. If they have a tendency to roll, they can be held down by a camel's-hair brush, or by attaching a section-smoother to the knife. After cutting, the embedding mass is to be dissolved out before staining. For this purpose, of the many solvents recommended, turpentine, naphtha, and xylol are the best.

METHODS OF STAINING.—As a rule, the sections to be stained are placed in the staining fluid from water, and allowed to remain in the former for various lengths of time—from a few seconds to twenty-four or forty-eight hours. The time depends on the nature of the stain and the result to be accomplished, and will be noted under

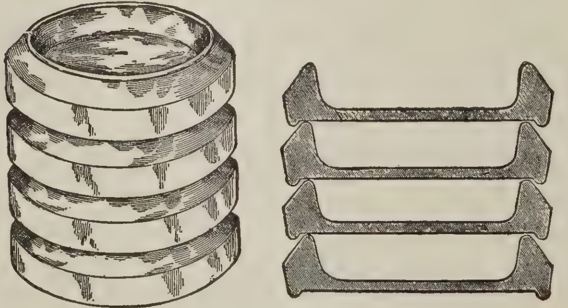

FIG. 2691.—Improved Syracuse Solid Watch Glass.

the various stains. After the staining is complete, the sections are to be washed in water, to remove all the excess of the staining fluid, mounted directly in glycerin, or, after dehydrating and clearing, in balsam.

For holding the stains and for the operations of washing, dehydrating, etc., we use small dishes of porcelain or glass, watch glasses, etc. The improved form of the Syracuse solid watch glass (Fig. 2691) will be found very convenient. For transferring the sections, the spatula or lifter (Fig. 2687), needles, camel's-hair brushes, glass rods, etc., are used.

Innumerable substances are used for the purpose of staining, and each year adds a host to the list, many of which are of doubtful value. Only the most important stains will be treated of here.

Carmine.—This dye, when first introduced, was used in the form of an ammoniacal solution, and is still, but rarely, employed in this form. Ammonia solutions are not stable; they undergo various chemical changes upon standing, so that the solution cannot be depended upon. Unless all free ammonia is driven off, the staining is apt to be diffuse. Various other solvents are now used with better results.

Tissues that are to be stained with carmine must be free from acid. Preparations hardened in chromic acid or solutions of chrome salts, must be well washed in water, and then they stain very slowly, requiring days. Obersteiner hastens the process of staining by heating the fluid to 50° C., and keeping it at that temperature for an hour, when the staining will be completed. Henle and Merkle soak sections in a 1 to 500 aqueous solution of palladium chloride for ten minutes; then in the carmine fluid for a few moments, when they become stained of a deep-red color. If the stain is diffuse it can be removed by placing the sections in a mixture of one part of formic acid and two parts of alcohol for from five to ten hours. This removes the stain, in sections of the central nervous system, from everything except the axis cylinders (Ranvier).

Before mounting, sections stained in carmine should be washed in a one-per-cent. solution of acetic or formic acid to fix the stain.

Carmine stains deeply nuclei, protoplasm, smooth and striated muscle, the basement substance of bone tissue and decalcified bone, the axis cylinders of nerves, etc.

Ammonia Carmine Solutions.—Ranvier's: Carmine, 1 gm.; ammonia, 1 c.c.; water, 100 c.c. Rub up the carmine in a mortar with a little water and add the ammonia. When the carmine is all dissolved add the rest of the water. If there is an excess of ammonia heat the solution until the carmine begins to precipitate.

Heidenhain's: Carmine, 1 gm.; ammonia, 3 c.c.; glycerin, 96 c.c.; water, 96 c.c. Dissolve the carmine in the ammonia and add the glycerin and water. Heat on a water bath until the excess of ammonia is driven off, or neutralize with acetic acid. The sections are placed in a watch glass of this fluid, and this, with a second watch glass containing water with a trace of ammonia, is placed under a bell glass for twenty-four hours. The sections at the end of this time are washed in water and exposed, as above, to the vapor of acetic acid, and mounted in glycerin.

Borax Carmine.—Grenacher's: The author gives two formulæ. In the first he dissolves 2 to 3 gm. of carmine in a solution of 4 gm. of sodium biborate in 100 c.c. of distilled water and then adds 100 c.c. of alcohol; filters, and after allowing the filtrate to stand a week, filters again. This solution is used chiefly for staining *in toto.* Pieces of tissue, according to their size, are placed in the solution for from one hour to three or four days; then in acidulated alcohol (three to four drops of HCl to 100 c.c. of seventy-five-per-cent. alcohol) for from one hour to three or four days. His second formula, known as neutral borax carmine, is as follows: 0.5 to 0.75 gm. of carmine is boiled in a solution of 2 gm. of sodium biborate in 100 c.c. of water. The solution is filtered, and acetic acid added to the filtrate until the purple tint changes to that of ordinary carmine; it is then filtered again. Sections stain in this fluid, in from one to three minutes, an intense and diffuse red color; they are then washed in a mixture of one drop of HCl to a watch glass of seventy-per-cent. alcohol, when the color is withdrawn from everything except the nuclei.

Lithium Carmine.—Oth's: Carmine, 2.5 gm.; saturated solution of lithium carbonate, 100 c.c.

After staining, the sections are washed in a mixture of 1 c.c. of HCl, and 100 c.c. of seventy-per-cent. alcohol, when the color is withdrawn from all except the nuclei.

Picro-carmine.—Ranvier's: Add ammonia carmine to a saturated aqueous solution of picric acid, until a cloudy precipitate begins to appear. Evaporate to one-fifth of its original volume, allow to cool, and filter. Evaporate the filtrate to dryness, when a reddish powder is obtained. This powder is used in one-per-cent. solutions in water.

Gage's: Take equal parts, by weight, of carmine and picric acid. Dissolve the picric acid in one hundred times its weight of distilled water, and the carmine in fifty times its weight of strong ammonia, mix the two solutions, and evaporate three-fourths at a temperature of 40° to 50° C. Allow the fluid to cool, and filter through two thicknesses of paper. Evaporate the filtrate to dryness at a temperature of 40° C., and dissolve the residue in one hundred times its weight of water. Make 50 c.c. of such a solution and filter through absorbent cotton packed in the neck of a funnel; repeat the filtering four or five times, when a clear solution should be obtained. If this is not the case, dissolve the remainder of the powder in the proportion given above, allow the solution to stand for a few days in a tall glass cylinder, and then decant the clear fluid. When a clear solution is obtained, add to every 100 c.c. of the picro-carmine 25 c.c. of strong glycerin and 10 c.c. of alcohol. This solution can be kept clear by filtering once in six months.

Weigert's: Soak 2 gm. of carmine in 4 c.c. of strong ammonia for twenty-four hours in a closed vessel; then add 200 c.c. of a saturated solution of picric acid in water, and allow it to stand for twenty-four hours. Filter, and add acetic acid to the filtrate, drop by drop, until a slight precipitate appears even after stirring. Allow this mixture to stand for twenty-four hours, when a precipitate will form which cannot be wholly removed by filtering; add ammonia, drop by drop, at intervals of twenty-four hours, until a clear fluid is obtained. If the solution stains too yellow, add a few drops of acetic acid; if too red, a few drops of ammonia.

Hoyer's: Dissolve 1 gm. of carmine powder (see Hoyer's Carmine) in 5 to 7 c.c. of ammonia and 1 to 5 gm. of picric acid in 50 c.c. of water. Mix the two solutions, and add enough water to make the mixture measure 100 c.c., and add 1 gm. of chloral hydrate for preserving. If any free ammonia is present, warm on a water bath until it is driven off.

Oth's: Mix one part of Oth's lithium carmine with two to three parts of a cold-saturated solution of picric acid in water.

Sections stained in picro-carmine should not be washed long in water, or the picric acid stain will be washed out. They may be mounted in balsam or glycerin; if the latter, the glycerin should be acidulated with a few drops of acetic or formic acid.

Alum Carmine Solutions.—Grenacher's: Boil one-half to one per cent. of carmine in a concentrated solution of ammonia or potash alum for from ten to twenty minutes, filter, and add a few drops of carbolic acid to the filtrate. Balbiani adds a few drops of acetic acid to a watch glass of this stain with good results. Tizzoni adds a little sodium sulphate, thereby increasing its staining power. This fluid stains quickly, and nuclei stronger than other parts.

Cochineal Fluids.—Mayer's: Soak 1 gm. of powdered cochineal in 10 c.c. of seventy-per-cent. alcohol, for at least three days. Filter, and use the deep-red filtrate for staining. Sections are placed in this fluid from seventy-per-cent. alcohol, and they stain in a few moments, or it may require several days, the time depending on the size and nature of the sections. When stained, wash in seventy-per-cent. alcohol until no more color comes away; then mount in the usual media. The results obtained by the use of this fluid vary with the nature of the tissue, and the presence or absence of certain salts—also upon the strength of the alcohol employed for solution. Overstaining may be removed by washing in one-tenth-per-cent. HCl, or one-per-cent. acetic acid.

Czoker's Alum Cochineal.—Boil 7 gm. of pulverized cochineal and 7 gm. of alum in 700 c. c. of distilled water, until the quantity of fluid is reduced to 400 c.c.; cool, add a few drops of carbolic acid, and filter. After allowing it to stand for a few days, filter again, when the fluid will be ready for use. Martinotti recommends the use of chrome alum in place of ordinary alum, and does not allow the temperature to go above 80° C. This fluid stains nuclei a hæmatoxylin color, other elements different shades of red. Alcoholic specimens stain quickly, in from three to five minutes; chromic-acid preparations require from three to five hours. After staining, specimens are washed in water and mounted in the usual media.

Carminic Acid.—The use of carminic acid in place of carmine was first suggested by Dimmock, but he used only aqueous or alcoholic solutions which gave but feeble stains. Mayer showed that in order to obtain suitable staining solutions of carminic-acid it must be combined with aluminum or calcium. I have found that the substitution of carminic acid for carmine in most of the formulæ given above makes a much better and sharper staining fluid.

Carmalum (Mayer).—Carminic acid, 1 gm.; alum, 10 gm.; distilled water, 200 c.c. Dissolve the carminic acid in the water and filter. Add a few crystals of thymol to prevent the formation of mould. After staining, wash out in distilled water, and if the plasma remains stained, wash in alum solution. This is a good fluid for staining tissues in bulk.

Hæmatoxylin.—This is one of the coloring substances contained in ordinary logwood. It is found in commerce in the form of reddish-brown crystals. Hæmatoxylin is not to be confounded with the ordinary crude extract which is sometimes sold under this name.

This dye is one of the best nuclei stains that we have, staining both alcoholic and chromic-acid specimens deeply and sharply. In chromic-acid preparations the color is likely to fade after a time, unless all the acid has been removed and the sections have been thoroughly dehydrated before mounting.

The clearest stainings are obtained with dilute solutions. After staining, the sections are washed well in water and mounted as usual.

Delafield's Solution: Saturated solution of ammonia alum, with an excess of crystals, 100 c.c.; to this is added 1 gm. of hæmatoxylin crystals dissolved in 6 c.c. of alcohol. This solution is allowed to stand in an unstoppered bottle in the light for four or five days, and then filtered. Then glycerin, 25 c.c., and wood naphtha, 25 c.c. are added; this is allowed to stand, as above, for from one to two days, and then filtered; the filtering is to be repeated at intervals, until all sediment ceases to form. It is to be diluted at least one-half with water for use.

Ehrlich's Acid Hæmatoxylin: Hæmatoxylin crystals, 1 gm.; strong alcohol, 60 c.c.; glycerin, 60 c.c.; water, 60 c.c., to which ammonia alum is added to saturation; hydric acetate, glacial, 3 c.c. This fluid is exposed to the light until it becomes of a deep-red color.

Gage's Hæmatoxylin: Distilled water, 200 c.c.; ammonia or potash alum, 7.5 gm.; this is boiled for five to fifteen minutes to destroy any germs in the water or alum; after cooling add 0.1 gm. of hæmatoxylin crystals dissolved in 10 c.c. of ninety-five-per-cent. alcohol and 4 gm. of chloral hydrate to prevent the development of germs.

For staining, this solution may be used full strength or diluted with alum water.

Up to a few years ago all formulæ for the preparation of hæmatoxylin solutions, especially those containing alum, ended with the following directions: "allow to stand in the light from eight to ten days before using." This was for the purpose of allowing the staining fluid to "ripen," as it is well known that freshly prepared solutions are of no use for staining.

This "ripening process" was found to be due to the oxidation of the contained hæmatoxylin and the formation of *hæmatein,* through the absorption of oxygen from the air. Paul Mayer and Unna found that this oxidation could be brought about immediately by the addition of a small quantity of hydrogen peroxide; Hansen, by the addition of potassium permanganate. I have hastened the process by passing air through the solution, using air compressed by the usual spray apparatus.

All hæmatoxylin solutions deteriorate in the course of time, the oxidation process continuing until precipitates form and the solution becomes colorless. Unna found that this over "ripening" could be delayed by the addition of a small quantity of sulphur. Paul Mayer used glycerin, and Gage, believing this to be due to the action of bacteria, sterilized his alum solution and then added chloral hydrate as a preservative. Owing to the investigations of Paul Mayer we are now in a position whereby *hæmatein* staining solutions can be quickly made, without the long "ripening" process.

Hæmatein, which Mayer uses in place of hæmatoxylin, comes in the form of dark greenish crystals or powder, and is freely soluble in alcohol and water. The commercial form is not always pure, and owing to this *hæmateate of ammonia* has been recommended in the place of hæmatein. This salt is also found in commerce, but of doubtful purity. It can be readily made in the laboratory as follows: One gram of hæmatoxylin crystals is dissolved, by the aid of heat, in 20 c.c. of distilled water and filtered. To this solution 1 c.c. of ammonium hydrate (sp. gr. 0.875) is added, and the dark purple fluid placed in a shallow porcelain dish, of such a size that the layer of fluid shall not exceed one-half a centimetre in depth. The dish is covered with filter paper, to exclude dust, and the solution is allowed to evaporate at the room temperature. The hæmateate of ammonia about equals in weight the hæmatoxylin used. In the preparation of this salt no metal instruments should be used until the powder is absolutely dry.

Mayer gives formulæ for three different solutions of hæmatein as follows:

Hæmalum.—Dissolve 1 gm. of *hæmatein* or *hæmateate of ammonia* in 50 c.c. of ninety-per-cent. alcohol, and add this to 1,000 c.c. of a five-per-cent. aqueous solution of *potash alum,* filter, and add a crystal of thymol to prevent the formation of mould. This fluid has a color resembling that of borax carmine. It may be used for staining in full strength, or it may be diluted with weak alum solution. In full strength it stains sections in about two minutes.

Acid Hæmalum.—This is prepared by adding two per cent. of hydric acetate to the above hæmalum solution. After staining, wash well in water to bring out the bluish tint of the nuclei. This solution is decidedly less diffuse in staining, and keeps better than the hæmalum.

Glycerin Hæmalum.—The above solutions of hæmatein do not keep well. To correct this, Mayer adds glycerin as a preservative. The solution is made as follows: Rub up 0.4 gm. of hæmatein in a mortar with a small quantity of glycerin; dissolve 5 gm. of potash alum in 70 c.c. of distilled water, and add 30 c.c. of glycerin. This mixture is gradually added to the hæmatein solution. This stain keeps well, but is somewhat slow in its action.

During the last year I have been using *hæmatein* in place of hæmatoxylin with the most satisfactory results. The staining fluid I have used is one made after a combination of Mayer's and Gage's methods. The solution is made as follows: A five-per-cent. solution of potash alum is made in distilled water and boiled, or what is better, placed in a steam sterilizer from one to one and a half hours. While this solution is warm, 0.001 per cent. of *hæmatein,* dissolved in a small quantity of alcohol, is added (it is my practice to keep a one-per-cent. alcoholic solution of hæmatein as a stock solution). After the fluid has cooled, 2 gm. of chloral hydrate should be added for each 100 c.c. of the staining fluid. This stain keeps well, and in full strength stains sections in from two to three minutes. It may be used diluted with distilled water, when the staining requires a longer time.

Heidenhain's Iron Hæmatoxylin.—Sections are placed in a 1.5 to 4 per cent. aqueous solution of ammonio-ferric sulphate, $(NH_4)_2,Fe_2,(SO_4)_4$, for from one-half to four hours; then they are washed in water; and then stained in a 0.5-per-cent. solution of hæmatoxylin in water for half an hour. They are then removed from the stain and washed in water. The sections which are now deep black are decolorized in the ammonio-ferric sulphate solution. This acts slowly and its progress should be watched under the microscope. This is done by removing the specimens, from time to time, from the decolorizer and examining them in water. As soon as a proper differentiation has been obtained the sections are washed in water for at least an hour, the water being changed several times. All chromatin elements of the nucleus stain black and are sharply differentiated.

ANILINE DYES.—*Fuchsin, Rosaniline Hydrochloride.*—Soluble in alcohol and water. Used for staining fresh tissue, blood cells, and connective-tissue cells. Chiefly used for staining bacteria. Merkle has used it for staining the structureless membrane of the retina.

Acid Fuchsin, Rosanilin Sulphonate.—(Fuchsin S, No. 130 of the Baden aniline factory.) First used by Weigert for staining the central nervous system, and now used chiefly in combination stains.

Safranin.—An oxidation product of pure toluol, of which there are numerous preparations on the market. The form usually used is safranin O, which is soluble in alcohol and water. This is a nuclei stain best suited for chromic-acid preparations.

Flemming dissolves one-tenth to five-tenths per cent. in a mixture of equal parts of alcohol and water. He stains sections for twenty-four hours; washes in weak alcohol, which frees them from part of the color, then in absolute alcohol until no more color comes away; then in oil of cloves only long enough for them to become penetrated, as it extracts the colors; mounts in balsam.

Babes recommends the following methods:

1. Sections of alcoholic or chromic-acid preparations are stained for half an hour in a warm, concentrated aqueous solution of safranin, or in a mixture of equal parts of concentrated aqueous and concentrated alcoholic solutions. They are then washed in absolute alcohol quickly, as it withdraws the stain, cleared in turpentine, and mounted in balsam.

2. For demonstrating the details of cell structure. A supersaturated solution of safranin in water is warmed to 60° C. and filtered. After cooling the solution becomes muddy. A small quantity of this fluid is placed in a watch glass with the sections, and warmed slightly over an alcohol lamp for a minute, when the fluid will become clear. The sections are then washed in water, cleared in turpentine, and mounted in balsam.

Safranin is also a good reagent for amyloid substance, staining it orange-yellow, other tissue rose-red. It is also used for staining elastic fibres.

Eosin (Erythrosin, Primrose).—This dye is found in commerce in two forms, one soluble in alcohol (tetrabromofluorescin), the other in water (a potash salt of the first).

Fischer, who first introduced the dye, precipitates the coloring matter from an aqueous solution with an acid; filters, washes the precipitate with water, and then dissolves the precipitate in alcohol. He prefers the alcoholic solution for chromic-acid preparations.

Eloui dissolves the eosin in glycerin, and after staining, fixes the dye with a saturated solution of alum in glycerin.

For general use a 1 to 1,500 solution in alcohol of the precipitated eosin will be found most convenient. Sections are stained for a few moments and mounted in glycerin tinged with eosin, as pure glycerin withdraws the color. For mounting in balsam the sections are dehydrated in the alcohol eosin and cleared in oil.

This dye, in combination with hæmatoxylin, is the best for general work, the hæmatoxylin staining the nuclei of the cells purple, while the cell bodies and intercellular substance are stained rose-red.

Methylene Blue.—An oxidation product of pure aniline, soluble in both alcohol and water. It is used chiefly for staining bacteria: in combination with eosin as a nuclear stain; in a chemically pure state in Ehrlich's method for nerve fibres; and in Nissl's stain for nerve cells.

Unna's Alkaline Methylene blue.—Methylene blue, 1 gm.; potassium carbonate, 1 gm.; water, 100 c.c. This solution is diluted in the proportion of 1 to 10 with water for use. It is a good nuclear stain in combination with eosin.

Methyl Green.—The double zinc salt of the base pentamethyltri-p-amidotriphenylcarbinolmethylate. Used in one-per-cent. aqueous solutions, and is chiefly a nuclei stain.

Carnoy employs it in a concentrated aqueous solution, to which is added one per cent. of acetic acid and one-tenth per cent. of osmic acid for staining fresh tissue. Nuclei stain sharply. The excess of color is washed out with water.

Curshmann recommends this dye as a reagent for amyloid, which it stains violet. It is also used in several of the multiple stains.

Iodine Violet, Hoffman's Violet (*a*, Dahlia, bluish tint; *b*, Primula, reddish tint). The pentamethyltriamidotoluyldiphenylcarbinol.

Ehrlich employs a saturated solution in a mixture of 500 c.c. of alcohol, 100 c.c. of water, and 12.5 c.c. of acetic acid. He stains sections for twenty-four hours; then washes in water acidulated with acetic acid, and mounts as usual. Protoplasm and connective tissue are partially stained; nuclei stain blue-violet. Sometimes the fat of fat cells and goblet cells stain.

Jürgens employs an aqueous solution as a reagent for amyloid, which stains bright red, while the rest of the tissue stains blue-violet.

Flemming employs the dye in the same manner as safranin.

Gentian Violet.—Employed chiefly for staining bacteria.

Methyl Violet.—The pentamethyltriamidotriphenylcarbinol.

Cornil found that aqueous solutions stained the cells of hyaline cartilage violet, the basement substance reddish, connective tissue, fibrillated and elastic fascia violet.

This dye is also used as a reagent for amyloid, which it stains red. According to Capparelli this reaction is an optical instead of a chemical one. He examined unstained sections by light transmitted through a thin layer of this dye and found that the amyloid substance appeared as if had been stained. He then examined unstained sections on glass stained with the colors of the spectrum, and found that in the section on the violet the amyloid substance appeared red, while the normal tissue appeared blue. His conclusion was that the amyloid substance permits the red rays to pass, but stops the violet.

This dye is also used in staining bacteria.

DOUBLE STAINING.—*Hæmatoxylin and Eosin.*—Sections are first stained in a solution of hæmatoxylin until they are of a distinct purple color, then washed well in water, and then stained in a dilute alcoholic solution of eosin. They can be mounted in either glycerin or balsam. If in glycerin, it is to be slightly tinged with eosin, or the color will be extracted from the specimen. If in balsam, the specimens are placed in alcoholic eosin, in which they become stained and dehydrated at the same time; then cleared in oil of origanum cretici, and then mounted in balsam or dammar. Nuclei stain purple, cell bodies and intercellular substance rose-red. This method is extremely useful for general work.

Eosin and Methylene Blue (Mallory).—Fix the specimens in mercuric chloride or Zenker's fluid.

Stain sections in a five to ten per cent. aqueous solution of eosin for from five to twenty minutes. Stain in Unna's alkaline methylene blue solution, diluted with from one to ten parts of water, for from one-half to one hour. Wash in water. Differentiate and dehydrate in ninety-five-per-cent. alcohol until the pink color returns in the sections. Clear in xylol and mount in xylol balsam or xylol dammar.

Nuclei stain blue, intercellular substance and cytoplasm red.

SPECIAL STAINS.—*Biondi-Heidenhain Triple Stain.*—Saturated aqueous solution of orange G, 100 c.c.; saturated aqueous solution of acid fuchsin, 20 c.c.; saturated aqueous solution of methyl green, 50 c.c.

Prepare the above solutions and let them stand for several days with an excess of the dyes. Then mix the solutions and dilute with water in the proportion of 60 c.c. of the staining solution to 100 c.c. of water. This dilute solution should redden upon the addition of hydric acetate; a drop of the mixture placed on filter paper should show a bluish-green centre and an orange periphery. If the orange zone is surrounded by a red zone, the mixture contains too much fuchsin.

Sections should be stained for from six to twenty-four hours. Those of tissues fixed in mercuric chloride give the best results. After staining wash in water; dehydrate in alcohol; clear in xylol; mount in xylol balsam or dammar.

Picro-Acid Fuchsin (Van Gieson).—Van Gieson introduced this stain for staining the peripheral nerves and sections of the central nervous system. His solution was not made up with any definite proportion of the acid fuchsin.

As the results of my experiments I have succeeded in establishing the following formulæ for the staining fluid: For connective tissue the proportions giving the best results are 5 c.c. of a one-per-cent. aqueous solution of acid fuchsin to 100 c.c. of a saturated aqueous solution of picric acid. For sections of the central nervous system the proportion of the acid fuchsin has to be increased and that of the picric acid diminished. The elements in this tissue stain more slowly, consequently the prolonged action of the picric acid removes the hæmatoxylin from the nuclei. The proportions of the staining agents that have given me the best results are 15 c.c. of a one-per-cent. solution of acid fuchsin to 100 c.c. of a half-saturated solution of picric acid.

Sections of tissues hardened in Müller's fluid or mercuric-chloride solutions—alcohol hardening does not give as brilliant results—are first deeply stained in hæmatoxylin (v. Kahlden recommends alum carmine) and then well washed in water. They are then placed in the picro-acid fuchsin fluid for from one to three minutes. Sections of the central nervous system require fully three minutes, those from other organs, as a rule, require only one minute. After the sections are removed from the staining fluid they are washed in two alcohols. I find that the addition of a small amount of picric acid to the second alcohol increases the brilliancy of the yellow stain. The sections are cleared in oil of origanum cretici and mounted in balsam.

This staining fluid, when used as above described, stains connective-tissue fibres a bright red; protoplasm, muscular tissue, and red blood cells, yellow. The hæmatoxylin stain in the nuclei is usually changed in color; sometimes it shows purplish-red, at other times black. Axis cylinders, nerve cells, and neuroglia fibres stain red.

Kantorwicz uses 150 c.c. of a saturated aqueous solution of picric acid and 3 c.c. of a saturated aqueous solution of acid fuchsin.

He stains sections in Delafield's hæmatoxylin for half an hour and then in the picro-acid fuchsin for from three to five minutes. He recommends the stain for cell inclusions.

Weigert's Stain for Elastic Fibres.—Boil basic fuchsin 2 gm., resorcin 4 gm., in 200 c.c. of water; while this is boiling add 25 c.c. of liquor ferri sequichlorati and continue the boiling for five minutes. Allow to cool and filter. The dark precipitate remaining on the filter is dissolved in 200 c.c. of strong alcohol by boiling the filter in it. Bring up the solution to 200 c.c. by the addition of alcohol; cool and add 4 c.c. of hydric chloride.

Stain sections for from one-half to one hour. Wash in strong alcohol until the color ceases to come away, then clear and mount in balsam.

Elastic fibres stain bluish-black.

Unna's Stain for Elastic Fibres.—Orcein (Grubler's), 1 gm.; hydric chloride, 1 c.c.; alcohol (absolute), 100 c.c. Sections are placed in the stain and warmed at a temperature of 30° C. for from ten to fifteen minutes. The stain becomes thick from the evaporation of the alcohol. Wash in seventy-per-cent. alcohol; dehydrate in strong alcohol; clear in oil of origanum, and mount in balsam. Elastic fibres stain a deep brown color. If a nuclear stain is wanted stain in Unna's polychrome methylene blue.

Weigert's Stain for Fibrin.—Stain sections of tissue fixed in alcohol or Zenker's fluid in aniline-gentian-violet solution for five minutes; place the sections on a slide and absorb the surplus stain with filter paper; then treat with iodine, 4 gm.; potassium iodide, 6 gm.; water, 100 c.c., for one minute; wash with water; decolorize in aniline, 2 parts, and xylol, 1 part, wash in several changes of xylol; mount in xylol balsam. The fibrin threads stain blue.

Jenner's Blood Stain.—Grubler's water-soluble eosin 1.2-per-cent. aqueous solution, 100 c.c.; Grubler's *pure* methylene blue, 1-per-cent. aqueous solution, 100 c.c. These solutions are mixed, allowed to stand for twenty-four hours, and then filtered. The precipitate is dried on the filter at 55° C., then washed with distilled water; dried and powdered.

For use, a 0.5-per-cent. solution of the dried powder is made in *pure methyl* alcohol. Cover-glass preparations and slide smears of blood are stained by immersing them in this solution for from three to five minutes; they are then washed in water; dried thoroughly in the air, and mounted in balsam.

METALLIC IMPREGNATIONS.—*Silver Nitrate.*—This is used chiefly for staining the cement substance between cells, especially the endothelium of serous membranes, lymphatics, and blood-vessels. It also stains the basement substance of connective tissue and cartilage. It may be used either in the solid state or in solution. The tissues to be acted upon must be fresh.

For membranes, silver nitrate is used in solutions of 1 to 300 to 1 to 500. The fresh membrane (omentum or mesentery) is carefully removed and stretched over the rim of a porcelain dish, filled with distilled water, and is allowed to sag in the centre so that both sides of the membrane will be immersed in the water; it is washed carefully by agitating the dish, so as to remove any blood or albuminous substance that may be on the surface. Now pour off the water carefully, and fill the dish with a 1 to 500 aqueous solution of silver nitrate. Agitate the dish frequently, and after from twenty to thirty minutes—when the membrane has become semi-opaque—pour off the silver solution and wash carefully with distilled water. Now transfer to a dish containing alcohol and water (1 to 2) and expose to the sunlight until it becomes of a brown color. This requires from twenty minutes to half an hour. Preserve in glycerin and protect from the light. The silver is deposited in the cement substance between the cells as an albuminate, and after being reduced by the action of the light, shows as fine black or brownish lines.

The cornea may be treated with silver in solution or in the solid state. In treating the cornea with the solid salt proceed as follows: Remove the eye and rub the anterior surface of the cornea with a piece of silver nitrate. Excise the cornea and place in distilled water; brush with a camel's-hair pencil to remove the epithelium. Then expose the cornea to the action of the light until it has become brown. Preserve in glycerin.

Silver in solution is applied as follows: Submit the cornea of a freshly killed animal to the action of a jet of steam, and scrape off the opaque epithelium, gently, with a scalpel. Allow a five-per-cent. solution of silver nitrate to flow over it, from a pipette, for two or three minutes; then wash with a one-per-cent. solution of sodium chloride; excise and expose to the light in a mixture of alcohol and water (1 to 2) until it becomes brown. Preserve in glycerin.

By these processes the basement substance becomes stained yellowish-brown, the cell spaces appearing as clear, irregular-shaped openings.

For injecting the blood-vessels, a fourth-per-cent. aqueous solution is used. The animal is bled to death, and the vascular system is washed out with distilled water;* this is followed by the silver solution, which is allowed to act for ten minutes and is then washed out with distilled water. Bits of thin membrane are removed and exposed to the light until brown, and then mounted in glycerin. In warm-blooded animals the solution should be heated to 30° C.; in cold-blooded animals the injection may be made at the ordinary temperature.

Hoyer adds to a solution of silver nitrate, of known strength, concentrated ammonia until the precipitate which forms is seen to be just barely redissolved; then dilutes this solution with distilled water until it contains from 0.5 to 0.75 per cent. of silver nitrate. This solution stains the cement substance only, leaving the ordinary tissues unstained.

Instead of reducing the silver by light I have employed an aqueous solution of hydrochinon (1 to 1,000), to which is added a few drops of a saturated solution of ammonium carbonate to render it alkaline. The tissue, after being treated with the silver, is placed in this solution until it becomes brown, which requires from five to ten minutes; then it is washed thoroughly in water and preserved in glycerin.

Auric Chloride.—Gold is reduced in the bodies of cells of cartilage, connective tissue, cornea, and epithelium, leaving the intercellular substance free; also in the axis cylinders of nerve fibres. It is very uncertain in its action, but when successful beautiful pictures are obtained. Tissues submitted to its action must be fresh.

Cohnheim's Method: Cohnheim, who introduced this salt, proceeds as follows: Bits of fresh tissue are placed in a one-per-cent. solution of auric chloride until they become yellow, and are then exposed to the light in water acidulated with acetic acid until the gold becomes reduced—until it becomes of a deep purple color; this requires from one to three days. The specimens are preserved in glycerin.

Löwit's Method: Löwit employs the following method for nerve terminations in muscle: Bits of tissue are placed in a mixture of 1 part formic acid and 2 parts water, until they become transparent; then for ten or fifteen minutes in a one-per-cent. solution of auric chloride until they become yellow; then in the formic-acid mixture for twenty-four hours in a dark place; then for twenty-four hours in pure formic acid in the dark. After this they are washed in distilled water and preserved in glycerin.

Ranvier's Method: Bits of fresh tissue are placed in fresh filtered lemon juice until they become transparent; then are washed in water and placed in a one-per-cent. solution of auric chloride for fifteen to twenty minutes; then again washed in water, and placed in dilute acetic acid (2 drops to 50 c.c. of water), and exposed to the light for two to three days, when the reduction will become complete. In the case of muscle Ranvier places the tissue from the gold solution in a twenty-per-cent. solution of formic acid in the dark for twelve hours, when the reduction is complete.

He also employs the following mixture: One-per-cent. solution of auric chloride, 4 parts; formic acid, 1 part; boil and allow to cool. Bits of fresh tissue are placed in this mixture for twenty minutes; then washed in water, and placed in formic acid 1 part, water 4 parts, in the dark for twenty-four hours.

Pritchard's Method: After the tissue has been treated with the gold solution, Pritchard reduces the gold with the following mixture: Amyl alcohol, 1 c.c.; formic acid, 1 c.c.; water, 98 c.c. The tissue is removed from the gold solution, washed in water, and placed in the above mixture for twenty-four hours in the dark, when it will probably have become of a violet color; if not, it is placed in a fresh quantity of the fluid for twenty-four hours longer. Wash in water and harden in alcohol.

Chrchtschonovitsch's Method: The fresh tissue is placed in a one-half-per-cent. solution of auric chloride for from thirty to forty-five minutes; then in distilled water for twenty-four hours; then in a saturated solution of tartaric acid, at a temperature of 50° C., until the gold is reduced; it is washed in water and hardened in alcohol.

Auric and Potassium Chloride.—This is of a more unvarying composition than the simple chloride; it is perfectly neutral in its reaction, and its solutions are more stable. It is used in solutions of the same strength as auric chloride. As a reducing agent Hoyer employs the ordinary pyrogallic acid developing solution used in photography. He adds one or two drops of this solution to 50 c.c. of water, and places the specimen in this for sixteen to twenty-four hours.

Osmic Acid.—The property possessed by osmic acid of staining fat black makes it a useful stain for the medullated nerve fibres. It also stains some other tissues various shades of black, but its action is uncertain. At present it is used chiefly for staining fat and nervous tissue.

It is best used in the form of vapor, as its penetrating power is then greater. The specimen to be submitted to the action of the vapor is pinned out on a cork fitted to a wide-mouthed bottle, in the bottom of which a few crystals, or a few cubic centimetres of a strong solution, of osmic acid are placed and left until the desired coloration is obtained.

It may also be used in solution in water or glycerin of the strength of from one-half to one per cent. Small bits of the tissue are placed in the solution for from one-half to twenty-four hours, and then washed thoroughly in water. Or a mixture of 1 part glycerin, 1 part alcohol, 1 to 3 parts water, and 1 part of a one-per-cent. solution of the acid may be used. Specimens may remain in this mixture for several days, until they are sufficiently stained.

All osmic-acid preparations should be preserved in glycerin.

Overstained specimens may be bleached by hydrogen peroxide.

Methods of Injecting.—*Self-injection of the Living Animal.*—This is accomplished by allowing a definite quantity of blood to escape from an opening in a vein of a living animal, and replacing the blood lost by some innocuous coloring matter, so that by the contractions of the heart the vessels are filled with much less injury than by an injection apparatus.

Chrzonszczewsky recommends a solution of 7.75 gm. of carmine in 3.6 c.c. of ammonia, to which is added 30 c.c. of distilled water. This fluid is to be filtered before injecting. Ten cubic centimetres of blood are removed from the jugular vein of a medium-sized rabbit, and 10 c.c. of the above fluid injected. If the larger vessels are now rapidly ligated, first the vein and then the artery, a physiological injection of the blood-vessels is obtained. Good results are obtained in the case of the kidney, spleen, etc. The injection may also be accomplished by placing the above fluid in the stomach, rectum, and abdominal cavity; and in amphibia by placing it in the lymph cavities. After the injection is accomplished the organs are placed in acidulated alcohol, to cause the fixation of the carmine.

This solution, as well as the sulphindilate of sodium, when injected in large quantities, is rapidly excreted by the kidneys, and the latter substance is precipitated in the biliary passages. If the ureter is ligated immediately after injecting a rabbit and the animal is killed at the end of an hour, the urinary tube will be found filled with carmine. In injecting the biliary passages it is not necessary to ligate. The blood-vessels of the organ are to be washed out and the original coloring matter that remains in them is to be replaced with another. The organs injected with the sulphindilate of sodium, after the blood-vessels have been washed out, are placed in a concentrated solution of calcium chloride, then in alcohol, when the coloring matter will become fixed.

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* Reich (Sitzber. d. Wien. Akad., 1873) uses a one-eighth to one-fourth per cent. solution of potassium nitrate in water for washing out the vessels.

Heidenhain found that the commercial indigo-carmine was composed of a mixture of substances, generally three in number: (1) indigo blue-sulphate; (2) indigo blue-hyposulphate; (3) phœnizine-sulphate of sodium. He found for the purpose of injection that 1 and 3 were the only ones useful. He injects 25 to 50 c.c. of a cold-saturated solution of one of the above salts into the vein of a medium-sized rabbit, and 50 to 75 c.c. into that of a medium-sized dog. After the animals have passed blue urine for some time they are killed by bleeding, and the coloring matter is fixed by injecting the kidney through the renal vessels with absolute alcohol.

For injecting the biliary passages of the frog, he places a piece of indigo-carmine, the size of a pea, in the lymph sac of the thigh, and closes the wound in the skin firmly. After twenty-four hours the biliary passages will be found beautifully injected.

Injection after Death.—For filling the vessels of an animal after death, or the vessels of a removed organ or tumor, we employ two kinds of injecting masses: one fluid, the other solid at ordinary temperature—cold- and warm-flowing masses.

Cold-flowing Masses.—If a solution of gelatin in water, to which is added a little ammonia, be boiled for several hours on a water bath, the gelatin is converted into metagelatin, and no longer congeals upon cooling. To this fluid, as a vehicle, may be added various coloring substances, when a good cold-flowing mass will be obtained. After injecting, the object is placed in formalin, which coagulates the metagelatin. The addition of glycerin and chloral hydrate, after Hoyer's method, will preserve the mass for some time.

Beale's Cold-flowing Fluid: Blue—Dissolve 0.777 gm. of potassium ferrocyanide in 30 c.c. of glycerin; mix 3.6 c.c. of tinct. ferri mur. with 30 c.c. of glycerin; add the iron mixture, drop by drop, to the potassium ferrocyanide solution. Then add to this mixture 5.5 c.c. of methylic alcohol, 30 c.c. of alcohol, and 88 c.c. of water, shaking strongly.

Carmine—Mix 1 gm. of pulverized carmine with a little water and sufficient ammonia to dissolve the carmine; add 50 c.c. of glycerin and shake well. Then add gradually, with constant shaking, 100 c.c. of glycerin, acidulated with 25 to 30 drops of HCl or acetic acid. Test the fluid with litmus paper, and if it is not decidedly acid add a few drops of acid. Then add 25 c.c. of alcohol and 75 c.c. of water.

Robin's Cold-flowing Fluids: Robin uses as a vehicle 2 parts of glycerin, 1 part of alcohol, and 1 part of water, combined with a third or a quarter of its volume of the following coloring masses:

Carmine—Rub up 3 gm. of carmine in a mortar with a little water and enough ammonia to dissolve the carmine; add 50 c.c. of glycerin, and filter. Add a ten-per-cent. solution of acetic acid in glycerin, drop by drop, until a slightly acid reaction is obtained.

Prussian Blue—(*a*) Potassium ferrocyanide (sat. sol.), 90 c.c.; glycerin, 50 c.c. (*b*) Liquor ferri perchloridi, 80°, 3 c.c.; glycerin, 50 c.c. Mix (*a*) with (*b*) slowly.

Green—Saturated sol. potassium arsenite, 80 c.c., and glycerin, 50 c.c., are mixed with saturated solution of cupric sulphate, 40 c.c., and glycerin, 50 c.c.

Yellow—(1) Cadmium sulphate (sat. sol.), 40 c.c.; glycerin, 50 c.c. (2) Sodium sulphide (sat. sol.), 30 c.c.; glycerin, 50 c.c. Mix (1) with (2) with constant shaking.

Warm-flowing Masses.—Robin's Gelatin Vehicle: One part of gelatin is soaked in seven, eight, nine, or ten parts of water, according to the consistence of the mass wanted, and when soft is melted on a water bath. This vehicle is then combined with any of the coloring masses just mentioned in the proportion of one part color to three parts vehicle. Filter through flannel before injecting.

Thiersch's Prussian Blue Mass: (1) A solution of gelatin, one part to two parts water; (2) saturated aqueous solution of ferrous sulphate; (3) saturated solution of potassium ferrocyanide; (4) saturated solution of oxalic acid.

Mix 12 c.c. of (2) with 30 c.c. of (1), at a temperature of 50° C. Mix at the same temperature 24 c.c. of (3) with 60 c.c. of (1), and add 24 c.c. of (4), with constant stirring. Add this solution to the solution of gelatin and iron; stir constantly until all the Prussian blue is precipitated. Heat on a water bath to 100° C., and filter through flannel.

Ranvier's Prussian Blue Mass: Prepare the Prussian blue as follows: Add to a saturated solution of ferrous sulphate, in water, a saturated aqueous solution of potassium ferrocyanide. Filter through a double filter of felt and paper. Wash with distilled water for several days, until the filtrate has a deep blue color. The Prussian blue has now become soluble. The precipitate is then dissolved in distilled water, and the solution kept in bottles until wanted.

Twenty-five parts of this solution are mixed with one part of gelatin. The gelatin is soaked for half an hour in water, and melted in the water it has absorbed, on a water bath. Heat the Prussian blue fluid to the same temperature, and mix with the gelatin solution, gradually, under constant stirring. Filter through flannel.

Thiersch's Carmine Mass: Carmine, 1 part; ammonia, 1 part; water, 3 parts. Dissolve and filter. Make a solution of gelatin in water, 1 to 2. Heat to 30° C. on a water bath, and add 1 part of carmine fluid for every 3 parts of gelatin solution. Then add acetic acid, drop by drop, stirring, until the free ammonia is used up. Inject at a temperature of 30° to 35° C.

Gerlach's Carmine Mass: Dissolve 5 gm. of carmine in a mixture of 4 c.c. of water and 0.5 c.c. of ammonia. Allow it to stand several days, and mix with 8 parts of a solution of gelatin, 1 to 2. Filter and inject at a temperature of 40° C.

Ranvier's Carmine Mass: Rub up 2.5 gm. carmine with a little water, and just enough ammonia to bring the carmine in solution. Soak 5 gm. of gelatin in water, and melt on a water bath in the water it has absorbed. Add the carmine fluid slowly, with constant agitation. Neutralize the free ammonia by adding, drop by drop, a mixture of acetic acid and water, 1 to 2. Filter through flannel.

Thiersch's Yellow Mass: (1) One part of gelatin in 2 parts of water; (2) 1 part of neutral potassium chromate in 11 parts of water; (3) 1 part of plumbic nitrate in 11 parts of water. Mix 4 parts of (1) with 2 parts of (3). In another vessel mix 4 parts of (1) with 1 parts of (2). Heat both mixtures to 30° C., and then combine, with constant stirring. Heat on a water bath to 90° C., and filter through flannel.

Thiersch's Transparent Green Mass: Combine the blue injection mass in various proportions with the yellow mass.

Frey's White Mass: Precipitate 125 to 185 c.c. of a cold-saturated, aqueous solution of barium chloride by adding sulphuric acid drop by drop. Allow the precipitate to settle for twenty-four hours, and decant the clear fluid. The remaining mucilaginous mass is mixed with an equal volume of strong gelatin solution.

Hartig's White Mass: Dissolve 125 gm. of lead acetate in enough water to make the whole weigh 500 gm. Dissolve 95 gm. of sodium carbonate in enough water to make the whole weigh 500 gm. One volume of each of the above solutions is mixed with two volumes of strong gelatin solution.

Fol's Dry Masses: Carmine—An indefinite quantity of ammonia is mixed with four times its volume of water, and carmine is added; after it has been standing an hour, with occasional shaking, no deposit should remain; then filter. Soak gelatin, in shreds, for two days in a sufficient quantity of the carmine solution. Then melt on a water bath with a small quantity of the solution. When melted add acetic acid until the color becomes blood-red, taking care not to add an excess of acid. Too little acid is not a disadvantage; too much will cause a granular precipitate. Allow the mass to cool, and tie up in a piece of coarse net, and by pressing with the hands, under water acidulated with 0.1 per cent. acetic acid, force the mass out into vermicelli-like strings. These are placed in a sieve, washed well with running water, and dried on waxed paper.

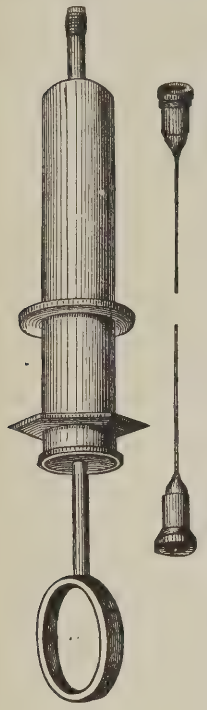
FIG. 2692.—Injecting Syringe.

Blue Mass—The mass is prepared according to Thiersch's formula. After cooling press out into vermicelli, as above, and dry on waxed paper. For use, soak the vermicelli in water; when soft, melt with enough saturated solution of oxalic acid to render the mass fluid.

Brown and Black Masses—Soak 50 gm. of gelatin in 200 c.c. of water in which is dissolved 14 gm. of sodium chloride. Melt on a water bath, and stir in briskly a solution of 30 gm. of silver nitrate, dissolved in 100 c.c. of distilled water. This produces a fine-grained, white emulsion, which is allowed to cool. When cold, press out into vermicelli, as above, wash in running water, and by clear daylight mix with the following: Cold-saturated aqueous solution of potassic oxalate, 300 c.c.; cold-saturated aqueous solution of ferrous sulphate, 100 c.c. When the mass has become black throughout, wash in running water for several hours, and dry the vermicelli on waxed paper. The color of this mass, by transmitted light, is sepia-brown. If a gray-black tint is wanted, substitute 24 gm. of potassium bromide for the sodium chloride in the first solution.

Injecting with a Syringe.—The syringe for this purpose should be made of brass or German silver, and should be of the form of that shown in Fig. 2692. Such a syringe, with half a dozen cannulæ of various sizes will answer all purposes for which a syringe can be used. It can be used only for injecting small organs.

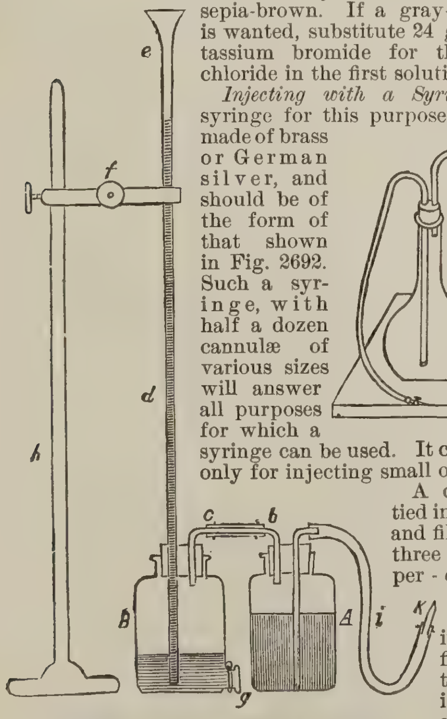

FIG. 2693.—Mercurial Injecting Apparatus.

A cannula is tied in the vessel and filled with a three-fourths-per-cent. salt solution. The syringe is then filled with the injecting mass, and to exclude all air the syringe is held vertically, nozzle up, and a few drops of the injecting mass are expelled. The nozzle of the syringe is then inserted in the cannula and the injection made slowly and steadily. On account of the difficulty of keeping up a steady pressure by the hand, the method of injecting with the syringe has been practically discarded.

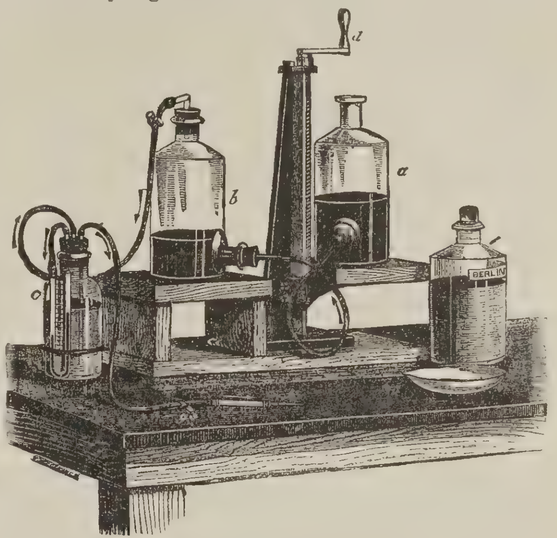

FIG. 2694.—Ludwig's Mercury-pressure Apparatus.

Injecting with Constant Pressure.—The pressure is obtained in this case by a column of mercury or water.

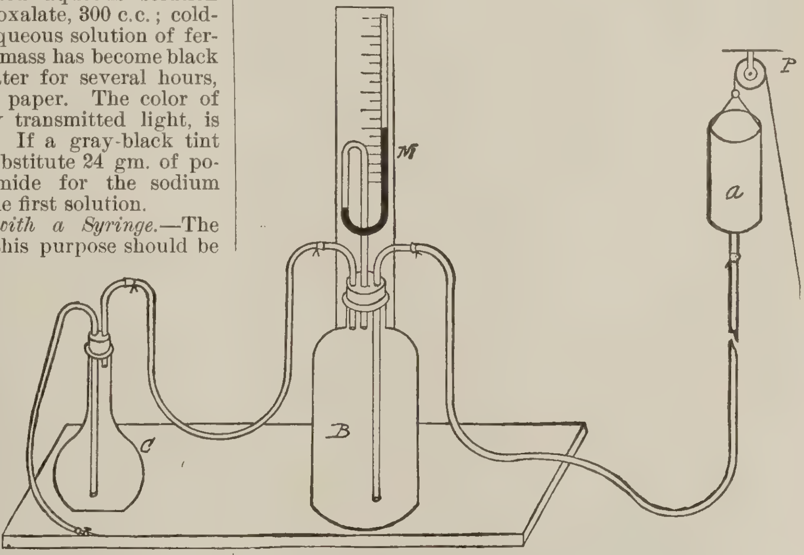

FIG. 2695.—Water-pressure Injecting Apparatus.

In Fig. 2693 is shown a simple form of a mercurial apparatus. The bottle *A* is filled two-thirds full with the injecting mass, which flows through the rubber tube *i*. The bottle *A* is connected with the bottle *B*, which is partially filled with mercury. The tube *d*, with a funnel end *e*, is fitted air-tight into the cork *B* (all joints must be air-tight). Upon pouring mercury into the tube *d*, it flows down into *B*, compressing the air, which in turn compresses the air in *A*, and forces the injecting mass out through *i*.

In Fig. 2694 is shown the more satisfactory apparatus of Ludwig. It consists of two Wolff's bottles, *a*, which contains the mercury, and *b*, into which, owing to the difference in the level of the two bottles, the mercury flows. This compresses the air in *b*, which, acting on the injecting fluid in *c*, causes the latter to flow out through the tube *g*. The pressure bottle *a* rests on a wooden support, which is raised by the screw *d*, until sufficient pressure is obtained. The mercurial manometer attached to the bottle *c* is for indicating the amount of pressure. If a gelatin mass is employed, the bottle *c* must be placed in a vessel of warm water.

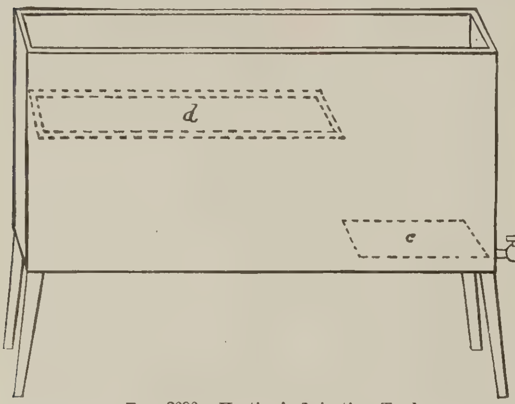

FIG. 2696.—Harting's Injecting Tank.

The water-pressure apparatus, Fig. 2695, is arranged as follows: The flask *C* is for holding the injection mass, and is connected with the pressure bottle *B* by a rubber tube. The manometer *M* is for measuring the pressure. The pulley *P* is fixed to the ceiling, and through it a rope pases which is attached to the can *a*, to the bottom of which is attached a rubber tube connected with the bottle *B*. The can *a* is filled with water which, upon raising the can, flows into *B*, compressing the air. The compressed air acting on the injecting mass, forces it through the rubber tube and cannula.

The amount of pressure can be regulated by the distance of the can *a* above the bottle *B*.

In using warm-flowing masses it is necessary that the object to be injected and the masses should be kept warm. The injecting tank of Harting, Fig. 2696, will be found very convenient for this purpose. The perforated shelf *c* is for the injecting flasks, the shelf *d* for the object to be injected. The tank is filled one-third full with water, which is heated by a Bunsen burner placed underneath.

In Fig. 2697 are shown several forms of injecting cannulæ. The two upper ones are made of brass, and should be of different sizes. The lower one is made from a piece of glass tubing. Several stopcocks, Fig. 2699, fitted to the brass cannulæ, are to be provided. Also a dozen or more serres fines (Fig. 2698), which are used for clamping leaking vessels.

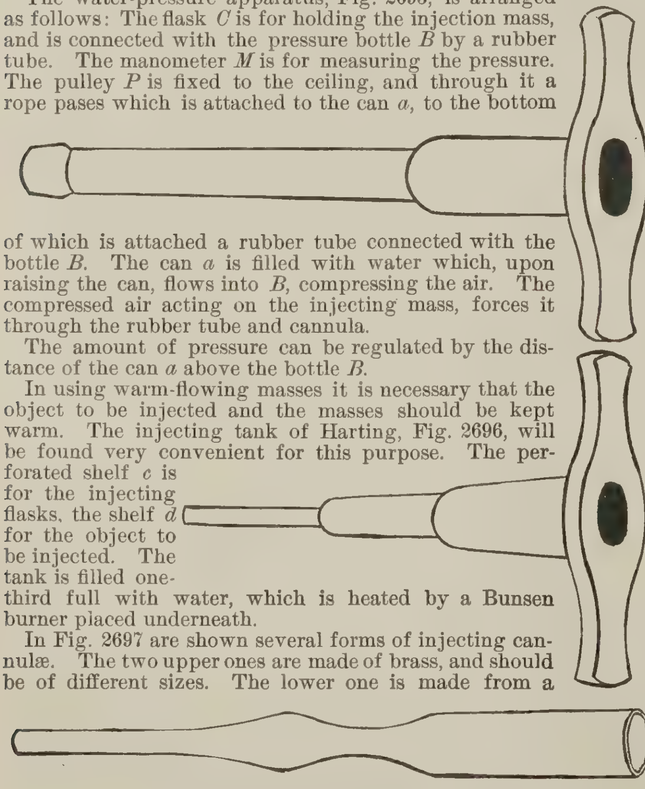

FIG. 2697.—Injecting Cannulæ.

Injecting an Entire Animal.—The animal—a rabbit or guinea-pig—is rendered insensible with chloroform. The thorax is opened by making an incision through the skin over the sternum and cutting out a small window over the base of the heart. The pericardium is opened, the heart pulled out and its apex cut off, the animal being allowed to bleed to death. The aorta is exposed, care being taken not to injure the vessels; a cannula is introduced (Fig. 2697) through the left ventricle into the aorta and fastened firmly with a ligature, the ends of the latter being tied around the arms of the cannula, or around the constriction of the glass one, if it be used. If a glass cannula be used, a piece of rubber tubing is attached to the large end and the whole filled with a three-fourths-per-cent. salt solution. The latter is retained by placing a spring clip upon the end of the rubber tube. The cannula is then introduced as above and tied.

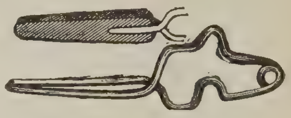

FIG. 2698.—Serres Fines.

The vessels are now washed out with a three-fourths-per-cent. salt solution. This is accomplished as follows: The animal is placed upon the shelf, *d*, of the injecting tank, Fig. 2696, the water in which has been heated by a Bunsen burner placed underneath. A flask, filled two-thirds with salt solution, is placed on the shelf *c*, and connected with the pressure bottle *B*, Fig. 2695. A piece of rubber tubing attached to a stopcock is connected with the delivery tube of the flask. The pressure is now applied by raising the can *a*, Fig. 2695, until the manometer registers about 50 mm. Now the stopcock is opened and all the air allowed to escape; then the stopcock is connected with the cannula introduced into the aorta. The salt solution is allowed to run through the vessels until it escapes perfectly clear from the right side of the heart.

The stopcock is now closed and disconnected from the cannula, and a flask containing the injecting mass is substituted for the one containing the salt solution. The stopcock is opened, and as soon as the injecting mass flows free from air bubbles the stopcock is connected with the cannula as above. The injection is continued until the mass flows from the right side of the heart, and is allowed to run for from twenty minutes to half an hour. A ligature is then tied around the vessels connected with the right side of the heart, and the injection is continued, the pressure being gradually increased to not over 100 mm., until the vascular system is filled, which can be judged from the color of the ears, lips, etc. When the injection is completed the vessels at the base of the heart are ligated, the stopcock is disconnected, and the animal put in a cold place until the gelatin has set. The organs and parts wanted are then removed and hardened in alcohol.

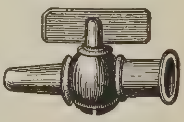

FIG. 2699.—Stopcock.

For injecting a single organ—the kidney—the animal is killed by bleeding, the abdominal cavity is opened, and the intestines are pushed aside. The renal artery is separated from its surroundings with forceps; then the renal vein in the same way. The artery is opened by a valvular opening, a cannula is inserted and firmly tied. An opening is then made in the vein. The organ is washed out with salt solution, which is followed by the injecting mass. The constant-pressure apparatus is to be used. After the injection is completed a ligature is passed around both vessels close to the organ, which is removed and hardened in alcohol.

For injecting pathological new formations, cold-flowing masses are to be preferred. The pressure employed must be moderate on account of the thinness of the walls of the blood-vessels. The serres fines will be in great demand for checking the leakage from the numerous lateral branches of the blood-vessels.

Double Injections.—Double injections are best made by injecting the artery and vein at the same time, with different colored masses—carmine for the artery, blue for the vein.

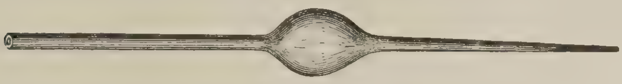

FIG. 2700.—Pipette.

A T-tube is attached to the outlet tube of the pressure bottle *B*, Fig. 2695, and from each arm a rubber tube is carried to flasks containing the injecting masses. These are then connected with the cannulæ fastened in the artery and vein. By this means both sets of vessels are filled at the same time and under the same pressure. The pressure at first must be low, so that the arteries and veins shall be completely filled before either mass passes into the capillaries. The pressure is finally increased, and each set of capillaries will be filled with its proper mass.

Injection of Lymphatics.—For injecting lymphatics the puncture method is the one chiefly employed. The puncture can be made from the cavity of a blood-vessel into the surrounding tissue, with the idea that a lymph vessel may be opened and that thus both sets of vessels may be injected. Or it may be made into the tissue and the injection made from this. The puncture must not be made at random, but in the direction in which small lymphatics are supposed to exist. The injection is made with a syringe fitted to the small cannula used for puncturing, and cold-flowing masses are to be used. If the extravasation is small and remains so, the injection is likely to succeed; but if the extravasation grows rapidly, the procedure is a failure and a new attempt is to be made.

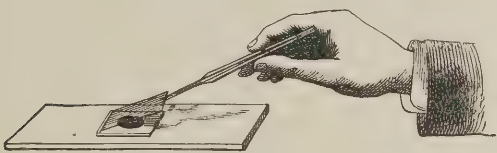

FIG. 2701.—Placing the Cover Glass in Position.

METHODS OF MOUNTING.—Specimens, after being duly prepared, are mounted on glass slides for study and preservation. The usual form of slide is known as the English. It is made of plate glass, measuring one by three inches, with the edges ground smooth. For covering the specimen thin pieces of glass, either circular or square in form, and of a size suitable to the specimen, are used. These are known as cover glasses.

The slides and covers, as received from the dealers, are generally covered with an oily material, making it difficult to clean them. This material may be removed in the following manner: Soak the slides and covers for twenty-four hours in a mixture of potassium bichromate, 960 gm.; sulphuric acid, 88 c.c.; water, 738 c.c.; then wash well in water. Wipe the slides dry with a clean linen cloth; place the cover glasses in alcohol until needed. Slides and covers that have been used are treated as follows: Put them into a mixture of equal parts of alcohol and hydrochloric acid, and, after a few days into the bichromate solution and treat them as new ones. Scrape the slides free of all balsam and put them in the bichromate solution.

In some cases, when we have an exceedingly delicate specimen, it is necessary to protect it from the pressure of the cover-glass. This can be accomplished by placing a hair under the cover, or we may make a shallow cell by painting a ring of some cement on the slide (see Fig. 2703). Again, we may have a thick specimen, or we may wish to use an aqueous mounting medium. In these cases thin glass cells are to be cemented to the slide, the specimen placed in them, and the mounting media added until the cell is filled; the cover-glass is then applied.

Mounting in Glycerin.—The specimens are either soaked in a small dish of glycerin until transparent, and then transferred to the slide; or they are placed on the slide from water, the excess of the latter being absorbed with filter paper or sucked up with a pipette (Fig. 2700), and a drop or two of glycerin is placed on the specimen, and the whole covered with a cover glass. In covering a specimen, care must be taken not to include air bubbles. If the cover glass is placed in position in the manner shown in Fig. 2701, any that may be present will be forced out with the excess of glycerin. The cover being in position, the superfluous glycerin is to be removed and the cover cemented down. All traces of glycerin must be removed, or the cement will not adhere to the glass. This is accomplished by washing out a camel's-hair brush in alcohol, absorbing the greater part of the alcohol by wiping the brush on filter paper until it is only moist, and then going over the slide in a systematic manner with the brush until all the glycerin is removed. A brush simply moistened with alcohol will not suck up the traces of glycerin; it must be well washed in the alcohol and dried very frequently.

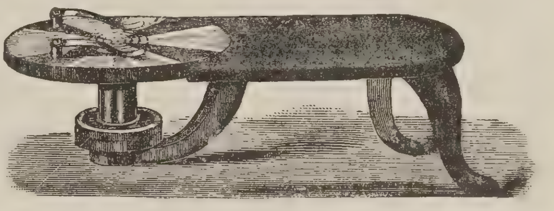

FIG. 2702.—Turn-table.

If the cover is a square one, it is cemented by passing a camel's-hair brush along the edge of the cover, whereby the latter as well as the slide receives a stripe of cement. Circular covers are easily cemented by aid of the turn-table (Fig. 2702). Concentric circles engraved on the surface of the table, according to the size of the covers, show where the brush is to be applied. The brush is to be held perpendicularly, and is filled with a cement of such a consistence that it will flow—it is not to be painted—on the cover and slide while the table is rotated. The manner of holding the brush and rotating the table is shown in Fig. 2703.

The glycerin penetrates the specimen, rendering it transparent, but on account of its high index of refraction, in some cases it renders the specimen too transparent, thereby concealing some of the minute structure. This objection can be overcome by mixing the glycerin with various proportions of water. As a rule, pure glycerin is to be used for mounting.

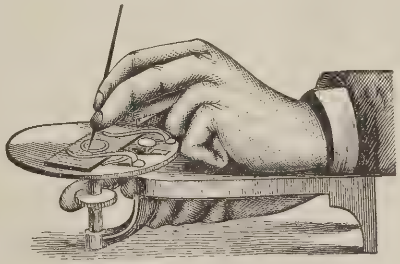

FIG. 2703.—Cementing Covers.

For cementing covers there are innumerable cements. Those that have stood the test of time are the following:

Asphalt Varnish. This can be procured from any painter's supply store, and is to be diluted with turpentine to the required consistency. Kitton recommends asphalt dissolved in benzol; to this solution he adds a little gold size.

Gold Size. What is known in commerce as Japan gold size is to be used. This sets very quickly, and may be used uncolored or colored with any of the mineral pigments.

Shellac Varnish. Shellac should be dissolved in alcohol, so as to obtain a thick solution. The addition of twenty drops of castor oil to each ounce of the solution has a tendency to render it less brittle. This is an excellent cement for specimens that are to be examined with oil-immersion lenses, as it is not attacked by the immersion fluid.

Gelatin. If the covers are first painted around with a warm, strong solution of gelatin in water, allowed to dry, and then painted with a saturated solution of potassium bichromate, an insoluble cement is formed which adheres firmly to the glass, and by the absorption of a small amount of glycerin that may be on the slide, is rendered semi-elastic. This is also a good cement for specimens to be examined by homogeneous immersion lenses.

Marine Glue. This is found in commerce already prepared. It is soluble in ether, naphtha, or solution of potash. It is used chiefly for making shallow cells, and cementing glass cells to the slide.

Mounting in Canada Balsam.—This process is divided into three steps: (*a*) dehydrating; (*b*) clearing; (*c*) enclosing in balsam.

(*a*) Dehydrating. As water is not miscible with the reagents used for clearing, or with the Canada balsam, it is to be removed. This is accomplished by soaking in absolute alcohol. The specimen is first washed in ordinary alcohol to remove the surplus of water, and then placed in the absolute alcohol for from three to five minutes.

(*b*) Clearing. For this purpose we must use a reagent that is miscible with both alcohol and balsam. The specimen is to be carefully removed from the alcohol with a spatula, the adhering fluid removed by filter paper, and the section floated off into the clearing medium. If the section is perfectly anhydrous it will float on this, and in the course of a few moments become transparent and sink to the bottom.

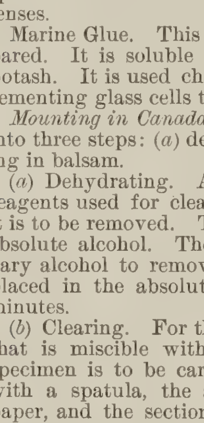

FIG. 2704.—Balsam Bottle.

For clearing we use chiefly the essential oils. Of the most commonly employed are the oils of cloves, cedar, anise, origanum cretici, bergamot, and the white oil of thyme. Carbolic acid, creosote, xylol, benzol, turpentine, and chloroform are also used. Old samples of wood creosote, xylol, benzol, chloroform, oil of origanum or thyme, are to be used for specimens embedded in celloidin, when we wish to retain the embedding material.

It is sometimes best to clear large or delicate specimens on the slide. First float the sections on the slide, and absorb the surplus alcohol with filter paper; then drop the clearing reagent on the specimen and place the slide under a bell-jar until the specimen is transparent; absorb the surplus of the clearing reagent, and add the balsam and cover.

(*c*) Enclosing in Balsam. The transparent section is removed from the clearing reagent with a spatula (Fig. 2687), and floated upon a slide, care being taken that it lies perfectly flat and that it is not wrinkled or folded upon itself. The excess of the clearing reagent is sucked up with a pipette (Fig. 2700), or soaked up with filter paper. A drop of balsam is placed upon the specimen, and the cover glass laid on as in glycerin mountings (Fig. 2701). As the balsam hardens in time, there is no need of cementing the cover. In all these manipulations great care must be taken to have the slides, covers, and all instruments perfectly dry—any moisture will cause a precipitation of the balsam, and thus cause an opacity of the specimen.

Canada balsam as found in commerce should never be used. The commercial balsam is heated on a sand bath until all volatile matter is driven off, and it becomes brittle when cold. This hard balsam is then dissolved in xylol, benzol, or oil of cedar, enough of the solvent being used to give the required consistence. These solutions, with the exception of that in oil of cedar, set quickly. The solutions of balsam are to be kept in capped bottles (Fig. 2704), or in tin tubes, such as are used for the oil colors of the artist.

Hard balsam is also used for mounting, especially sections of hard bone and teeth, in which we wish to demonstrate the lacunæ. The process is as follows: A bit of hard balsam is placed in the centre of a slide and warmed gently over the flame of a lamp, care being taken not to let it boil, or bubbles will be formed. When melted, the specimen is plunged into it and covered quickly, and the slide is placed on a cold surface, which sets the balsam immediately and prevents its entering any of the lacunæ, which, being filled with air, show as dark spaces.

Instead of Canada balsam, dammar varnish and other preparations of dammar may be used. Gum dammar dissolved in xylol or oil of cedar is now generally used in place of the above mixtures.

Glycerin Jelly.—Of the numerous published formulæ for this medium, that of Kaiser is the best. He soaks one part, by weight, of French gelatin for two hours in six parts, by weight, of distilled water; then adds seven parts of glycerin and 1 gm. of carbolic acid for every 100 gm. of the mixture; warms on a water bath, with constant stirring, until all the flakes produced by the carbolic acid disappear; filters warm through paper and preserves in a tightly stoppered bottle.

Soak the sections for a short time in this warm mixture, and then transfer to a melted drop of the same on a slide. Cover, and when the jelly has set, remove any excess and ring the cover glass.

For Weigert's hæmatoxylin method, and its modifications, for the central nervous system; Golgi's methods of impregnation with silver chromate; Nissl's method for staining nerve cells; Ehrlich's method of staining nerve fibres with methylene blue, and its modifications; Marchi's method for staining degenerated nerve cells; and Weigert's and other neuroglia stains—see *Brain, Histology of*, Vol. II., pp. 322–331.

For further details of histological methods consult "The Microtomist's Vade-Mecum," Bolles Lee; "Pathological Technique," Mallory and Wright; *Zeitschrift für wissenschaftliche Mikroskopie.* *George Cornell Freeborn.*

HODGKIN'S DISEASE.—(Synonyms: Pseudo-leukæmia, lymphadenoma, anæmia lymphatica, adenia, lymphosarcoma, malignant lymphoma, lymphomatosis.)

Definition.—A disease characterized by a progressive enlargement of the lymph glands and often of the spleen, a gradually developing anæmia, and secondary growths of lymphoid tissue in the liver, spleen, kidney, alimentary tract, bone marrow, and other structures of the body.

The affection differs from leukæmia chiefly in the absence of a marked leucocytosis.

Etiology.—The disease occurs most frequently in males under forty years of age. The exact etiology of Hodgkin's disease is as obscure as that of leukæmia. The fact that the disease often follows inflammatory processes and runs a rapid febrile course suggests an infectious origin. Bacteriologic examination of the blood and lymph glands has revealed micro-organisms in over fifteen cases. The Staphylococcus pyogenes aureus, the Streptococcus pyogenes, the pneumococcus of Fraenkel, and unidentified bacilli have been cultivated. Roux and Lannois claim to have reproduced the disease by injecting animals with a coccus cultivated by them from the blood and lymph glands of a case. Delbet claims the same for a bacillus. The multiplicity of organisms found suggests that all are probably accidental.

PATHOLOGY.—The most important morbid changes in Hodgkin's disease are hyperplasia of the lymph glands, enlargement of the spleen, and the presence of lymphoid growths in the liver, bone marrow, and intestinal tract.

Lymph Glands.—As a rule, the lymph glands show the greatest change. The glands involved in order of greatest extent and frequency are the cervical, axillary, inguinal, retroperitoneal, bronchial, mediastinal, and mesenteric. In addition, the popliteal and epitrochlear glands may be enlarged. The lymphatic structures of the mouth and alimentary tract are relatively infrequently involved. Lymphoid nodules in the liver are often observed. Microscopic collections of lymphoid cells may be found in various organs that present no abnormal naked-eye appearance. The glands of the neck are usually largest. They vary in size from a hen's egg to minute nodules; unless crowded together, the glands are freely movable, and not attached to the skin. Glandular enlargement is usually symmetrical, although one side may be more extensively involved. Rarely the process is confined to one side. The natural shape of the enlarged gland is round or oval. Pressure may produce many alterations in form. A thin capsule surrounds each gland, and when not crowded together, loose connective tissue unites them in chains. The enlarged glands may be soft or hard. On section, if no secondary changes, such as hemorrhage, have occurred, the surface presents a soft mass, grayish-white in color, with a faint tinge of red or yellow. In the soft variety the cut surface bulges beyond the capsule, and a turbid fluid, made up largely of lymphoid cells, may easily be expressed. No stroma is apparent. The hard variety possesses a relatively greater reticulum than a normal gland. Little or no fluid exudes from its cut surface. Enlargement of the thoracic glands may compress the bronchi or trachea. Thrombosis of large thoracic veins may occur from pressure. The heart and lungs may be displaced by enlarged glands. Lymphoid growths may occur in the lungs; rarely the aorta, thoracic duct, and œsophagus are compressed by the posterior mediastinal glands. The recurrent laryngeal nerve may be injured. In the abdomen the retroperitoneal glands are most frequently involved; the mesenteric seldom reach a large size. Displacements of the uterus and compression of the ureters have resulted from growth of the pelvic glands.

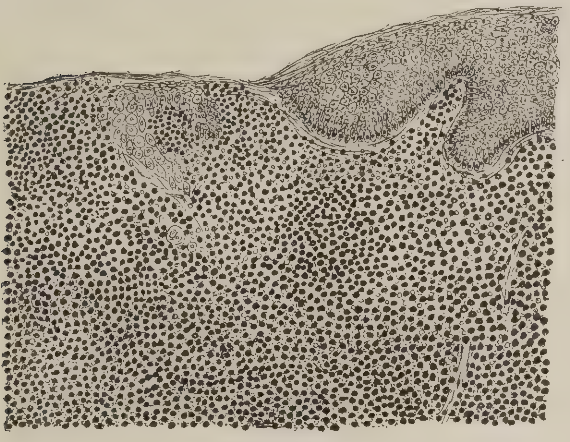
FIG. 2705.—Adenoid Growth in the Skin. (Author's case of Hodgkin's disease.)

Histology of the Lymph Glands.—The microscope shows hyperplasia of all the elements of a lymph gland. In the soft variety the increase in the lymphoid cells is relatively much more marked than that of the connective tissue. Cells presenting the appearance of ordinary lymphocytes are crowded together and held in position by an exceedingly fine network of fibrils. In the hard variety the parenchyma is likewise made up of lymph cells but the connective-tissue increase predominates. Widely varying grades of sclerosis may exist in the different cases and in the various groups of glands in the same case. The gross appearance and histologic change in the lymph glands are practically identical with those in lymphatic leukæmia.

Spleen.—Hyperplasia of the spleen exists in eighty per cent. of all cases. In the splenic variety of the disease the hyperplasia may be enormous, the organ at times filling the greater part of the left half of the abdominal cavity. In the majority of cases of the usual type of the disease, the enlargement is moderate in degree, the spleen rarely exceeding thirty ounces in weight. The organ is firm and its original shape is preserved. Local thickening of the capsule due to perisplenitis may exist. The enlargement may be a true hypertrophy. In about seventy-five per cent. of the cases in which the spleen is enlarged, however, lymphomata are found varying in size and number. The histologic structure of the spleen approaches more closely than normal the picture of a lymph gland. As a rule, the pulp is relatively more increased than the lymph sinuses and reticular tissue. Even in the hard variety of splenic enlargement the increase in the lymphocytes predominates. Sclerosis of the Malpighian bodies is now and then found. Degenerative changes in the lymphoid cells do not occur, as a rule.

Liver.—The organ is often slightly enlarged. Lymphoid growths varying in size from a minute point to a hazelnut invade the liver structure. They develop in the interlobular spaces, and may grow between the liver cells.

Bone Marrow.—A fœtal condition of bone marrow is usually present, similar to that in pernicious anæmia. Adenoid growths are found in the medulla.

Alimentary Tract.—Adenoid growths in the digestive canal seldom attain large size. They may be scattered along its entire length. The tonsils, glands at the base of the tongue, Peyer's patches, and solitary follicles may become hyperplastic. Ulceration of adenoid growths in the stomach may take place. Lymphomata may develop in the kidney, lung, testicle, thymus and thyroid glands. They are sometimes found in the dura; now and then they involve the cranial and peripheral nerves. Lymphomatous growths are practically never found in the brain and spinal cord. Adenoid growths have been found in the heart. In rare cases the skin is the seat of adenoid growths. Retrograde metamorphoses in the new-formed tissue rarely take place in true Hodgkin's disease. When marked changes are present, the condition is usually tuberculosis or mixed infection.

SYMPTOMS.—In the majority of cases Hodgkin's disease begins insidiously and progresses gradually to a fatal termination. In rare instances, however, the onset is severe; and its course rapid. The important symptoms of the disease are progressive enlargement of the lymphatic glands, a gradually developing anæmia, associated with a relative increase in the lymphocytes, enlargement of the spleen, loss in strength and weight, irregular temperature, œdema, and grave cachexia.

Lymph Glands.—As a rule, the earliest symptom noted by the patient is enlargement of the lymph glands superficially located. In most instances the cervical glands are the first involved; rarely the inguinal or the axillary glands are the first to become affected. A few cases have been described in which anæmia, loss of weight and strength, apparently preceded glandular enlargement. At times the deep thoracic or abdominal glands are diseased first, producing early pressure symptoms, such as pain in the chest, cough, dyspnœa, or pain in the abdomen or legs, with œdema. If the cervical group is primarily affected, the enlargement is usually confined to one side for a time. It may be several months before the other side is involved. The glands of the posterior triangular space and those which lie beneath the jaw are usually enlarged first. In the early stage of the disease the enlarged glands are not adherent to the skin or to each other. As the disease progresses, periadenitis may unite the glands in a firm mass. Such masses in the cervical region may project far beyond the angle of the jaw and produce great deformity of the neck. The larynx may be pushed to one side, and grave dyspnœa has resulted from narrowing of the trachea by pressure. Pressure effects upon the carotid artery, jugular vein, and pneumogastric nerve have been noted. Enlarged glands in the thorax have produced spasmodic cough, dyspnœa, paralysis of the vocal cords, œdema of the arms and lower extremities. Enlargement of the axillary glands has resulted in pain and swelling of the arms from compression of nerves and veins. The inguinal glands may compress the femoral vein; the retroperitoneal glands are sometimes palpable. Bronzing of the skin, possibly from pressure on the sympathetic plexus, has been observed in a few cases. The enlarged glands may compress the ureters, interfere with the function of the lumbar and sacral nerves, and produce œdema by occluding the iliac vein. Uterine fibroids may be simulated when enlarged glands become adherent to the uterus or broad ligament. As a rule, the glands of rapid growth are softer than those that grow slowly. Pain is not present, except when nerve trunks are compressed. Glands of very rapid growth are sometimes tender on pressure. The rapidity of growth varies in different cases, and in the different groups in the same patient. Not infrequently the glands become smaller for a short time. Under the influence of an erysipelas, a marked temporary reduction in size has been noted.

Spleen.—Moderate enlargement of the spleen is present in about eighty per cent. of the cases. No special symptoms referable to this organ are present in the common form of Hodgkin's disease. In the splenic variety, the spleen may attain enormous size. Bruits have been heard; pain from perisplenitis is often present.

Anæmia.—Anæmia is one of the characteristic features of the disease. It may not be pronounced until glandular enlargement is of considerable extent. As the anæmia develops, the patient complains of dizziness, tendency to syncope, headache, dyspnœa on exertion, and cardiac palpitation. Pallor of the mucous membranes appears. The skin assumes a hue peculiar to anæmia. The conjunctivæ become subicteric. Epistaxis may occur. The advent of cachexia is characterized by a tendency to œdema, effusion into serous cavities, marked asthenia, hemorrhages, and fever.

Circulatory System.—The heart is usually somewhat dilated. Hæmic murmurs may be heard. In the later stages the carotids pulsate visibly. The veins are often prominent. The pulse is full and frequent, and may approach the water-hammer character. Retinal hemorrhages may take place.

Blood.—In the early stages of Hodgkin's disease the blood may show no marked alteration.

Red Cells.—As the disease progresses there is usually a gradual reduction in the number of red cells, and the individual cell is moderately poor in hæmoglobin. The loss in red cells and hæmoglobin does not approach that found in a corresponding stage in leukæmia; even at the time of death the red cells may number two million or more per cubic millimetre. In a few cases they have been reduced to less than one million per cubic millimetre. As a rule, no marked change in the size and form of the red cells is present. Occasional megalocytes are found, but more frequently the corpuscles are undersized. Nucleated red cells of the normoblast type are usually scarce, even in the late stage of the disease.

Leucocytes.—The number of leucocytes may be normal or even diminished. In the majority of cases of true Hodgkin's disease, the lymphocytes are relatively increased. The polynuclear cells are correspondingly decreased.

In many cases the number of leucocytes is markedly increased, although, as a rule, no greater than fifty or sixty thousand per cubic millimetre are found. The rapidly developing cases, with febrile disturbances, are more likely to show a leucocytosis than those of chronic course. A few myelocytes may be found, as in all cachectic processes. The eosinophiles are rarely increased. The coagulability of the blood is greatly reduced. A diagnosis of Hodgkin's disease cannot be made on the blood findings alone. A relative lymphocytosis is a valuable sign, but the same condition is often found in true lymphosarcoma, and in tuberculosis of the lymph glands.

Alimentary System.—The tonsils and glands at the base of the tongue are frequently enlarged. Deafness may arise from extension of adenoid growths from the pharynx, occluding the Eustachian tube. Ulceration of lymphoid growths in the stomach may simulate gastric ulcer. Diarrhœa and hemorrhage may occur from the same condition in the intestinal tract. Constipation may result from pressure of enlarged glands; jaundice from occlusion of bile ducts. The liver is often enlarged, due at times to the growth of lymphoid tissue in its structure.

Temperature.—A moderate elevation of temperature from time to time is the rule in Hodgkin's disease.

Respiratory System.—Dyspnœa incident to anæmia or pressure on the respiratory passages by lymphatic growths is a common symptom. Crepitant râles, produced by the pressure of adenoid growths in the lung may be heard. Pleural transudates take place in the cachectic stage. The terminal event is often a pleurisy or a pneumonia.

Nervous System.—Paraplegia may result from pressure on the spinal cord, as in a case reported by Osler. Epileptiform convulsions of short duration may occur. Coma may precede death. Disturbance in function of nerves from pressure is frequent.

Genito-Urinary System.—The urine often contains a trace of albumin. A real nephritis is to be considered a complication.

Skin.—Bronzing, such as occurs in Addison's disease, has been observed. Adenoid growths in the skin presenting small raw surfaces, from which serum exudes, have been observed in a few cases. In one recently studied by the writer, the growths progressed over the surface of the skin, leaving behind a healed surface, slightly indurated (Fig. 2705).

Diagnosis.—Hodgkin's disease is clinically and anatomically closely related to several affections.

Leukæmia.—The essential difference is in the blood findings. A few cases of Hodgkin's disease have terminated in true leukæmia.

Tuberculosis of the Lymph Glands.—Musser and others believe that Hodgkin's disease is probably a lymphatic tuberculosis. Most observers, however, are of the opinion that Hodgkin's disease and tuberculosis of the lymph glands are two distinct affections. All admit the difficulty at times in differentiating the two processes, both clinically and anatomically. The following points are of some value in distinguishing the two processes:

1. Localized glandular enlargement favors tuberculosis.
2. Fever is often absent in Hodgkin's disease. A fever is usually present in tuberculosis.
3. In Hodgkin's disease, deposits of lymphoid tissue may be found outside of the glands.
4. In tuberculous disease, the glands often caseate or suppurate, and become adherent by inflammation to each other and to the skin. In Hodgkin's disease the glands do not caseate or suppurate, and are freely movable beneath the skin.
5. The tuberculin test often results in local reaction in tuberculous adenitis. The positive diagnosis of Hodgkin's disease had better be reserved in all cases until tuberculous lymphadenitis has been excluded by animal inoculation and histologic examination.

Chronic Intermittent (*Rückfalls*) *Fever.*—This condition is characterized by a chronic intermittent fever, with swelling of the lymph glands. It was brought into prominence by Pel, Ebstein, Renvers, and others. It is probably a tuberculous lymphadenitis.

Lymphosarcoma.—This condition, sharply differentiated by Kundrat, is clinically and anatomically more closely related to Hodgkin's disease than to sarcoma of the lymph glands. However, the glandular enlargements possess some of the characteristics of malignant growths. Like Hodgkin's disease, they originate in lymphatic structures, although in perhaps one-half of the cases they do not develop from typical lymph glands, but from glandular elements, such as are found in the mucous membrane of the mouth and alimentary canal. The growths remain more regional than in Hodgkin's disease. They develop along the line of the lymphatics; extremely rarely do metastases occur through the blood. Universal glandular enlargement, as in Hodgkin's disease, does not occur. Histologically, the cells often present atypical development, contain at times many nuclei, become distinctly aggressive, penetrate the capsule, and invade the surrounding tissue. The glandular structure of the growth is often effaced. In many cases the histologic picture is the same as in Hodgkin's disease. Metastases in distant organs rarely occur. Retrograde metamorphoses do not occur as a rule. In rare instances lymphosarcoma develops from Hodgkin's disease.

Splenic Anæmia.—Splenic anæmia presents the clinical and histological picture of Hodgkin's disease, with the exception that the spleen is the lymphatic structure that is chiefly involved. The organ may be enormous in size. Enlargement of the lymph glands is absent, or decidedly in the background. It is, in reality, the splenic form of Hodgkin's disease.

Syphilis.—Glandular enlargement in syphilis is in the group nearest the indurated sore. Rarely does the adenopathy become general. One gland becomes enlarged first, the others of the group soon afterward. They seldom are larger than a hazelnut. In the secondary or tertiary stage of the disease glandular enlargement may be present in the proximity of a local syphilitic lesion.

PROGNOSIS, COURSE, AND TERMINATION.—The onset of the disease varies. Acute cases have been described by Cohnheim, Eberth, and Falkenthal. In one case the duration of the disease was only eleven days; in another four and one-half months. The most rapid course has been noted in children. The majority of cases are fatal within the first two years. Few last longer than five or six years. The most favorable cases are those in which glandular enlargement remains localized. General lymphatic enlargement may occur early, or it may rapidly develop after several years of local involvement. As a rule, soon after glandular hyperplasia becomes general, anæmia and emaciation develop, and the disease progresses steadily to a fatal termination. The immediate cause of death is often some intercurrent affection, such as pneumonia or pleurisy. Cases have been reported in which death occurred from asphyxia and starvation, due to pressure of enlarged glands upon the trachea or œsophagus. In a case recently observed by the writer, general convulsions and transitory unconsciousness were repeated several times during the day preceding death. Recovery has apparently taken place under treatment. The slowly developing cases are more likely to be benefited than the acute. Even in the latter arrest or improvement may occur. The prognosis is best in the splenic form of the disease, because it is amenable to surgical treatment.

TREATMENT.—Patients affected with Hodgkin's disease should avoid physical and mental fatigue. They should receive nourishing food, easily digested. Lean meats, milk, cream, butter, and eggs are especially valuable foods.

Medicinal Treatment.—Arsenic is recognized as the best drug. It may be given internally in the form of Fowler's solution, or arsenious acid. Certain advantages accrue from its subcutaneous administration. Injection of arsenic directly into the enlarged glands is advocated. When Fowler's solution is given internally, it is well to begin with two drops, three times a day, after meals, and gradually increase the dose by from one to three drops each day. If no symptoms of arsenical intoxication appear, the dose may be increased to fifteen or twenty or thirty drops three times a day. Should symptoms of arsenical poisoning appear, such as pronounced metallic taste, salivation, nausea, severe epigastric pain, vomiting, diarrhœa, tenesmus, irritable heart action, oppressed breathing, œdema, tremor, and muscular stiffness, the dose should be reduced to the point of tolerance. If a diarrhœa of moderate grade is the only symptom of intoxication, it can often be advantageously controlled by giving from three to six drops of the simple tincture of opium, three times a day. If no diarrhœa exists, it is well to administer laxatives and diuretics to help free the system from arsenic, and its products of altered metabolism. Arsenious acid may be given in the form of the so-called Asiatic pill: one part arsenious acid to eighty parts black pepper. Black pepper seems to increase the tolerance of the stomach for arsenic. Marked improvement sometimes follows the internal administration of arsenic. In chronic cases, glandular swellings have rapidly disappeared, and in some instances recovery has followed its use. Even in the rapidly developing cases, arsenic has apparently checked the course of the disease. In many cases of Hodgkin's disease, arsenic may be given to better advantage subcutaneously. The disagreeable gastro-intestinal symptoms are delayed, and much larger doses of the drug are tolerated. Pearson's solution produces the least local irritation. It is best injected in the region of the buttocks, or in localities rich in subcutaneous areolar tissue. It should be diluted with equal parts of distilled water, the mixture sterilized, and the skin and instrument rendered thoroughly aseptic. Pain, which sometimes continues for a short time after the injection, may be controlled by adding one-tenth grain of cocaine hydrochlorate. The injections may be given once daily, and subsequently twice daily. Gradually increasing doses may be given each day, until a larger amount than advised by mouth may ultimately be given and tolerated for a longer time. The effect of the subcutaneous injection of Pearson's solution is often very gratifying. The general condition may improve, the glands may diminish in size, and the patient often gains in weight. Severe pain is rarely complained of at the site of the injection. If care is taken in the preparation of the solution and instruments, inflammation and suppuration do not occur. Good results are claimed for the injection of Pearson's solution directly into the enlarged glands. This sometimes gives rise to a slight elevation of temperature. Such injections have been made directly into the enlarged spleen. The wisdom of this procedure may be justly questioned.

The manner in which arsenic acts in Hodgkin's disease is not known. If the disease is bacterial in origin, its effect may be germicidal; possibly it acts in the same manner as mercury in syphilis. Unfortunately, only a relatively small number of cases are permanently benefited by arsenic, and in a few cases no improvement follows its use. Iron is of very little value in the treatment of the disease. Quinine and phosphorus in small doses have seemed to be of some use. Cod-liver oil is a good tonic. Extracts from various glands and tissues have been used without apparent results.

Local Treatment.—Aside from the intraparenchymatous injection of arsenic, already described, the enlarged glands have been injected with solutions of various drugs. Iodine, potassium iodide, nitrate of silver, carbolic acid, and chromic acid have been used, without satisfactory results. Galvano-puncture has proved of no permanent value. Iodine applied to the skin over the gland is ineffectual. If the disease is primarily located in the glands, and if the disease spreads from them by secondary infection, an early removal of the glands primarily diseased would be rational. The subsequent course in a number of cases in which the disease was local and the glands were early removed justifies the procedure in selected cases. If the disease is widespread and deep-seated from the beginning, extensive operative treatment is not advisable. Some think it best to remove as many glands as possible, even though the glandular enlargement is general, in the hope that medicinal treatment may better control the disease. The results obtained do not warrant the procedure. All cases, chronic in character, with a tendency to localization of the process, should be treated by removal of the growths, supplemented by the administration of arsenic. Operation is indicated when accessible growths produce serious pressure symptoms. In most cases the glands are easily removed. In some cases, however, adhesions are firm and extensive. The results obtained by splenectomy in the splenic variety of the disease are exceedingly gratifying. A removal of the spleen should be seriously considered in all cases in which the diagnosis is certain, and the progress of the disease is apparently toward a fatal termination. Recovery has followed splenectomy in such cases, even after cachexia was advanced.

Bertram W. Sippy.

HOLARRHENA.—*Conessi* or *Tellicherry Bark.* The bark of *H. antidysenterica* Wall. (fam. *Apocynaceæ*), a woody plant of India. It is one of several plants whose barks have gone under the name of "Kura" or "Kuda" in India. The active constituent is an alkaloid which has been called *Wrightine* ("conessine"), and there is some doubt about its identity with what has been regarded as the same from other sources. It is contained also in the seeds. The bark appears to be a carminative and intestinal astringent, and the alkaloid somewhat antiperiodic. It is very largely used in native practice in India as an antidysenteric, and has been considerably so used in Europe. Reports as to its efficacy are discordant, but its use has declined. An aqueous extract is used in three-grain doses. *Henry H. Rusby.*

HOLOCAIN, para-diethoxy-ethenyl-diphenyl-amidin hydrochloride $[(C_6H_4.O.C_2H_5)_2.NH.C.CH_3{:}N.HCl]$, is obtained by the union of molecular quantities of phenacetin and paraphenetidin with separation of water. It crystallizes in bitter, white needles which are freely soluble in alcohol and ether and in forty parts of water. It is not affected by a temperature of 212° F. (100° C.). With alkalies it is decomposed and precipitated, the presence of a calcium salt in the water used for solution being sufficient to produce turbidity. It attacks any free alkali in glass; so, to prevent precipitation, the glass container should previously be boiled with acid.

Holocain has a deleterious effect on protoplasm, as in 0.1-per-cent. solution it stops fermentation and putrefaction, in 0.5-per-cent. solution it arrests the development of germs, and in one per cent. it stops amœboid movements and kills most micro-organisms. Hence the solutions are sterile, though if desired they may be boiled without harm. Holocain paralyzes the sensory nerve endings, and is a local anæsthetic of great power. It is claimed by Hotz, Wurdemann, Knapp, Jackson, and others to be quite as anæsthetic in the eye as cocaine, quicker in its action, and its effect more lasting, and as it is more penetrating the iris is more anæsthetized. It does not dry the cornea, increase intraocular tension, or influence the pupil or accommodation. Neither does it constrict the vessels, and, on the contrary, it tends to produce slight hyperæmia. This comparison with cocaine can be well demonstrated by dropping cocaine solution in one eye, and holocain solution in the other eye of the same patient. The amount used for eye work is two to five drops of one-per-cent. solution, and in one-half to two minutes this produces anæsthesia lasting ten to fifteen minutes. Derby and Knapp recommend it for the removal of foreign bodies as it leaves so little effect on the eye. They also find it the most serviceable drug in corneal ulcers of microbic origin, and in purulent ophthalmitis. Holocain cannot be used like cocaine by hypodermic for local anæsthesia, as it is much more toxic, its action in overdose resembling that of strychnine (Heinz).

W. A. Bastedo.

HOLZIN, HOLZINOL. See *Formaldehyde.*

HOMATROPINE.—Atropine and hyoscyamine when decomposed break up into tropic acid and tropin. The latter when combined with mandelic acid forms homatropine; mandelic acid being the product of the action of hydrochloric acid on amygdalin. Homatropine combines with acids to form salts; the hydrobromide, hydrochloride, and salicylate are those most employed. The hydrobromide is official in the British Pharmacopœia. Pure homatropine is almost insoluble in water but is slightly soluble in oil and vaseline. A two-per-cent. solution in oil and gelatin discs are prepared for ophthalmic work. The advantage claimed for the solution in oil is that it is not so readily washed from the eyes by the tears. Homatropine is weaker in its action than atropine and when administered internally acts in much the same manner as does the more common alkaloid. It is said to differ from the latter in this respect, viz., it causes a slowing of the pulse, but this difference is not marked when large doses are administered. The dose of the hydrobromide as given by the British Pharmacopœia is from one-eightieth to one-twentieth of a grain. It has been recommended for use in all conditions in which atropine is indicated, particularly in the night sweats of phthisis. It, however, has not been much employed, as it has not proved so trustworthy as atropine.

Homatropine is almost entirely employed as a mydriatic in ophthalmic work. Its action is much less intense than that of atropine, but it dilates the pupil and paralyzes the ciliary muscle almost as rapidly, and its effects pass off in a much shorter time. The pupil begins to dilate in ten or twenty minutes and paralysis of accommodation is complete in about one hour. In from twelve to twenty-four hours its action is quite recovered from. A one- or two-per-cent. solution is used. *Beaumont Small.*

HOMBURG, GERMANY.—This popular watering-place is situated in the Rhine land, ten miles north of Frankfort-on-the Maine. It is reached from Paris, from which it is 477 miles distant, direct by rail, or viâ Cologne and the Rhine.

The town is built on a spur of the Taunus Mountains at an elevation of 643 feet above sea level. Its natural situation is not picturesque, but art has done much in the way of beautiful pleasure grounds, extensive parks, and promenades. It contains 9,278 inhabitants and is annually visited by 10,600 persons, forty per cent. of whom are said to be foreigners, including a large number of English. Homburg has been one of the favorite resorts of the late Prince of Wales, now King of England.

The mineral springs and sanatoria are in a large Kurpark which extends toward the northeast into the forests of the foothills of the Taunus.

The climate is that of Central Germany, the average yearly temperature being 47.5° F.; and for summer, May, 56.3° F.; June, 66.2° F.; July, 65.6° F.; August, 66.5° F.; September 56.3° F. The yearly rainfall is 26.6 inches. The season extends from May to the end of September.

The waters of Homburg are saline-chalybeate, and are derived from the Taunus schist and quartzite. The principal constituents are the chlorides of sodium, calcium, magnesium, and lithium; the carbonates of iron and calcium; and free carbonic acid. Unlike the waters of Ems, they are cool and have to be artificially heated when used for baths. They come under the general classification of common salt or muriated waters and are similar to those at Wiesbaden, Kissingen, Baden-Baden, Kreuznach, and Nauheim.

There are seven springs, as follows, with their temperatures: Elizabethbrunnen, 51.1° F.; Ludwigbrunnen, 53.4° F.; Louisenbrunnen, 52.1° F.; Landgrafenbrunnen, 51.8° F.; Kaiserbrunnen, 52.9° F.; Stahlbrunnen, 51.8° F.; Soolsprudel, 51.8° F.

The Louisenbrunnen and Stahlbrunnen are distinguished by their excess of carbonate of iron. All these springs are used for drinking except the Soolsprudel and Landgrafenbrunnen.

The Ludwigbrunnen, Kaiserbrunnen, Louisenbrunnen, and Soolsprudel are used for bathing, the water being warmed by hot steam chambers at the bottom of the baths, with the least possible escape of carbonic acid gas. The waters of the Ludwigbrunnen are used for inhaling. All the springs are the property of the town of Homburg, which has erected the various bath-houses: the Kaiserbrunnen with sixty bathrooms, and two piscinæ for natural carbonic-acid salt baths; mud baths and mineral and fresh-water baths: Kurhausbad with thirty-three bathrooms. In the former 26,147 baths were given in 1899, and in the latter over 7,000. In the Kaiser Wilhelm's bath are inhalations with spray produced by compressed air.

Besides the mud baths mentioned there are pine-needle, electric, medicated, and steam baths; and there are also good facilities for Swedish gymnastics and massage, as well as for the milk and whey treatment.

The chief centre for visitors is the Kurhaus, containing handsome apartments, reading-room, etc., with a terrace partly covered with glass, and corridors, affording a sheltered promenade. At the back of this Kurhaus extend the beautiful pleasure grounds, with a palm-house, orangery, and well-kept flower beds.

The town contains water-works, a sewerage plant with facilities for filtration, and a steam disinfecting apparatus.

Therapeutics.—When these waters are taken internally they gently stimulate the gastric and intestinal mucous membrane, at the same time rendering the contents of the bowels more fluid; they are therefore beneficial in catarrhal affections of the alimentary tract. Taken in small quantities they are constipating, but laxative in larger quantities. They help to increase the general nutrition, according to Weber, by their action in aiding the digestion of albuminous materials.

According to the same authority, they often increase the weight in thin persons, and for such cases are preferable to the alkaline-sulphated waters.

They are also beneficial in catarrhal affections of the respiratory tract; in gout, uric-acid diathesis, obesity, hemorrhoids, diseases of women, heart disease, and malaria. Those springs containing iron are useful in cases of anæmia and chlorosis.

Fifty-five thousand litre bottles of these waters are yearly exported. *Edward O. Otis.*

HONEY.—MEL. "A saccharine secretion deposited in the honeycomb by *Apis mellifica* L. (class, *Insecta;* order, *Hymenoptera*)" (U. S. P.). For the collection and sources of honey, the reader is referred to the article *Wax.* Freshly separated from young or "virgin" combs it is a pale yellow, or greenish-yellow, or light sherry-colored liquid, about as thick as glycerin, of peculiar odor, and of very sweet and slightly sharp taste. All these properties vary with the conditions of its collection, such as season, the prevailing flowers, climate and country, and (but not in commercial honey) the species of insect producing it. The honey of older combs is darker colored and more disagreeable. With age, after removal from the combs, it becomes darker, and granular from the formation of crystals of sugar in it. Specific gravity 1.430 to 1.440. The following tests and reactions are from the Pharmacopœia:

"When recent honey is diluted with two parts of water, the resulting liquid should be almost clear, not stringy, and should have a specific gravity not lower than 1.100 (corresponding to a specific gravity of 1.375 for the original honey).

"Honey has a faintly acid reaction toward litmus paper.

"If one part of honey be dissolved in four parts of water, a clear or nearly clear solution will result, which should not be rendered more than faintly opalescent by a few drops of silver nitrate T.S. (limit of *chlorides*), or of barium chloride T.S. (limit of *sulphates*).

"If one volume of honey be diluted with one volume of water, and a portion of this liquid gradually mixed with five volumes of absolute alcohol, it should not become more than faintly opalescent (as compared with the reserved portion of the solution), and should neither become opaque nor deposit a slimy substance on the inner walls and bottom of the test tube. And when honey is incinerated, in small portions at a time, in a platinum crucible, it should not leave more than 0.2 per cent. of ash (absence of *glucose* and *foreign inorganic substances*).

"On boiling one part of honey with five parts of water, the resulting solution, when cold, should not be rendered blue or green on the addition of iodine T.S. (absence of *starch*)."

Of this, the Pharmacopœia provides a clarified form, under the title "*Mel Despumatum*, or *Clarified Honey*," which is required to respond to the above tests and which we are directed to prepare as follows:

"Mix the honey intimately with *two* (2) *per cent.* of its weight of paper pulp, which has been previously reduced to shreds, thoroughly washed and soaked in water, and then strongly expressed and again shredded. Then apply the heat of a water-bath, and, as long as any scum rises to the surface, carefully remove this. Finally, add enough distilled water to make up the loss incurred by evaporation, strain, and mix the strained liquid with *five* (5) *per cent.* of its weight of glycerin."

COMPOSITION.—Honey is a solution of several sugars in water, together with minute quantities of several acids (lactic, acetic, etc.), coloring matter, mucilage, albuminoids, and the odorous principles. Occasional pollen cells are seen in it, and, when old, crystals of sugar. The sugar of honey is principally *levulose*, or uncrystallizable fruit-sugar, but *dextrose* and even sometimes *saccharose*, or cane-sugar, are also present; *mannit* has been observed. In old honey these crystalline sugars (which perhaps increase in it with age at the expense of the levulose) are the cause of its granulating. The result of six analyses by König were: fruit-sugar, 78.74 per cent.; cane-sugar, 2.69 per cent.; nitrogenous substances, 1.29 per cent.; water, 16.13 per cent. (Hager).

Poisonous substances are frequently found in honey, apparently collected by the bees. Their origin has sometimes been traced to *Rhododendron* and other members of the *Ericaceæ*, but no method of detecting them, except by eating, has been found. The poisoning is usually mild, but numerous fatal cases have been recorded.

USES.—The employment of honey as an article of food and luxury, as well as a medicine, is of great antiquity, and extends over nearly every temperate country on the globe. In the tropics the bees are less provident, and honey is not so regularly collected. But, in spite of this popularity, honey has no medicinal value beyond that of sugar or syrup, and can be considered only a vehicle for other medicines. Partly as a convenience on account of its taste and consistence, and in part from deference to tradition, it has been used in numerous preparations; it is still official in the Honey of Rose (*Mel Rosæ*, U. S. P.), made by mixing 12 parts of a fluid extract of red rose (vehicle, diluted alcohol) with 88 of honey. It is simply a pleasantly astringent vehicle. Confection of rose contains twelve per cent. of honey. *W. P. Bolles.*

HONTHIN is a tasteless and odorless compound of tannin, keratin, and albumin, which is said to pass through the stomach unchanged, and to be separated into its constituents in the intestine. It is an intestinal astringent, is insoluble in water, and may be given alone or with chalk mixture for diarrhœa or intestinal fermentation (Reichelt, Frieser). *W. A. Bastedo.*

HOOF-AND-MOUTH DISEASE.—Hoof-and-mouth disease, also known as foot-and-mouth disease, is spoken of technically as epizootic aphtha, and has also been called eczema epizootica, vesicular aphtha, vesicular epizootic

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(The author acknowledges his indebtedness for many of the above facts to "Deutschlands Heilquellen und Bäder," herausgegeben vom Kaiserlichen Gesundheitsamt zu Berlin, Berlin, 1900.)

and aphthous fever; among the ignorant the term murrain is sometimes used.

In France it is officially known as *fièvre aphtheuse,* and is also spoken of as *stomatite aphtheuse* and *cocette.* The Germans call it *Maul- und Klauenseuche, Maulfaule, Apthenseuche, Bläschenkrankheit,* and *Maulweh.* In Italy it is known as *afta epizootica, febbra aftosa,* etc. In the far East it is also found, being called in Bengalee *Homsa, khoorea, khoora, khoraha,* and other names; in Thibet it is known as *khuchha,* and in Singalese as *kata ledé* and *kura ledé.*

Hoof-and-mouth disease is peculiar to the cloven-footed domestic animals, the ox, sheep, goat and swine, but may be communicated by them to the horse, dog, cat, and poultry, and also to man. It is this latter property that renders it of special interest to the practitioner of human medicine. It may also occur among wild ruminants, such as deer, buffalo, camel, llama, giraffe, and antelope.

Hoof-and-mouth disease in cattle, sheep, and swine is characterized by a vesicular eruption of the mucous membrane of the mouth and under surface and edges of the tongue, the interdigital space and around the top of the foot at the juncture of the hair and horn, followed by ulceration as the vesicles break, and accompanied by high fever.

It is highly infectious, being disseminated not only by the cohabitation of sick with healthy animals, but also by manure, litter, stable utensils, the clothes and boots of attendants and veterinary surgeons, and by cattle cars. Even driving healthy cattle over roads previously traversed by cattle suffering from the disease is sufficient to produce it in the non-infected animals.

Milch cows suffering from hoof-and-mouth disease also have a vesicular eruption upon the udder and teats, and in these cases the milk becomes a medium of infection.

Hoof-and-mouth disease has undoubtedly existed for centuries, probably for the last two thousand years; it seems to be a native of Western Asia and Eastern Europe, and has long been known in India and upon the steppes of Russia. As commerce between civilized nations increased and means of communication developed, it spread over Europe from the east to the west until now it prevails from the Caspian Sea to the Atlantic Ocean. It also exists in India, Ceylon, Burmah, and the Straits Settlements. With the development of literature its description became more accurate and accounts of its spread over Europe in the seventeenth and eighteenth centuries show it to have prevailed extensively in Italy, Germany, and France. Toward the end of the eighteenth and early in the nineteenth century it reached Western Europe, but did not gain access into England until 1839, and was not known in Denmark until 1841.

Hoof-and-mouth disease seems to be a native of localities in Eastern Europe or Western Asia, and an exotic in some other countries. For example it was imported into Canada in 1870, being introduced by two Shorthorn cows brought from Liverpool, and appeared in localities in New York State and some of the New England States; but it does not seem to have assumed a severe form and in a few months entirely disappeared, and to-day it does not exist upon the North American continent. Its behavior in thus disappearing may be in part due to its having been introduced in the autumn, and as cattle in the North are housed during the winter months there is very little communication between herds; but it may also in part be due to its exotic character. The last outbreak in the United States was in the early eighties (about 1884), when some cattle imported from England were landed at Portland, Me., and driven to the United States quarantine station a short distance away. Soon after a yoke of oxen was driven over the same road, which later developed hoof-and-mouth disease,—the imported cattle having it when landed,—and gave it to the owner's herd; but the disease was soon suppressed, and there has been no reappearance of it since.

The United States Bureau of Animal Industry, of the Department of Agriculture, spares no pains to protect the live-stock interests of the country from contagious animal diseases; hence it is unlikely that this malady will ever secure a foothold here, owing to the stringent quarantine regulations imposed by the federal Government. Cattle, sheep, swine, and other ruminants can be brought into the United States only at points designated by the Department of Agriculture, the ports of entry on the Atlantic seaboard being only at Boston, New York, and Baltimore, near which places quarantine stations have been established. All neat cattle are held at these stations for ninety days, and all sheep and swine for fifteen days after landing. The reason for holding cattle longer is to guard against contagious pleuropneumonia; the period for which the sheep and swine are held is sufficient to guard against all danger from hoof-and-mouth disease. Neat cattle also have to be found free from tuberculosis as determined by the tuberculin test before being allowed to go beyond the quarantine station limits. Separate gates and lanes are provided for entrance and exit; if, therefore, any contagious disease should make its appearance, there would be no danger of healthy animals becoming infected by being driven over roads where sick animals had previously been.

Importers of animals from England or Europe must also obtain permits from the Department of Agriculture, and furthermore must have affidavits that animals come from localities free from contagious diseases, and do not pass through infected districts in transit. The collector of the port of entry is notified when the animals arrive, and immediately turns them over to the care of the agent of the Bureau of Animal Industry having charge of the quarantine station.

In countries where hoof-and-mouth disease has prevailed as an epizootic, the losses occasioned by it have been very great to the farmer from a pecuniary standpoint; not that the mortality is very large, as only from one to three per cent. of the infected animals die, but owing to the emaciation due to the fever, and the inability to walk about and eat. This loss is especially heavy when cattle or sheep are being fed for the shambles. Animals nearly ready for the butcher in a few days lose all the flesh that it has taken them months to put on.

Neat cattle have the severest lesions in the mouth, as a rule, and have great difficulty in eating, although lameness may also be present, while among sheep the foot lesions are usually the more severe and they will not walk about in search of food, but spend most of their time lying down.

In Great Britain, after its introduction in 1839, there have been several epizootics of hoof-and-mouth disease. Professor Brown has classified them as the ten great outbreaks, but it seems to have been pretty well subdued there, as from 1886 to 1896 only 1,295 cattle, 3,673 sheep, and 107 swine have been reported as having it, and during 1897 no authentic cases were reported. These results have been brought about only by the most strenuous efforts; when an outbreak has occurred public live-stock markets were closed, infected cattle quarantined, cars and premises disinfected, litter destroyed, and every precaution taken to check the spread of the disease. The results have amply justified the means adopted. Previous to 1886 the occasional great outbreaks assumed very large proportions. For example, in 1871 there were 700,000 cases among cattle in England with 7,000 deaths (one per cent.), and an equally bad outbreak occured in France at the same time. While it seems to have been nearly eradicated in Great Britain, epizootic aphtha still prevails extensively on the Continent with occasional sudden increases, in spite of a good sanitary veterinary police system in every European country. For example, in Belgium, in 1897, there were 2,453 cases of hoof-and-mouth disease; in 1898, 15,553; in France there were 1,601 outbreaks in 1897, and in 1898, 9,458; and in Italy 3,216 cases in 1897, and 45,497 in 1898.

In Hungary, in 1896, 572,809 cattle, 178,612 sheep, and 82,931 hogs were infected, while in 1897 it was diminished to 70,491 cattle, 25,450 sheep, and 3,758 hogs.

In the pig, as in the sheep, the lesions are manifested chiefly on the feet, although there may be eruptions on the snout and free borders of the lips. Sows suckling young may have an eruption on the mammæ and teats, but in the sow and ewe this is not so frequent as in the cow. Young pigs infected through milk have the mouth and intestinal lesions, and in a severe form.

The period of development from the time of exposure is short, usually from three to eight days; but it may not appear in rare instances, it is said, for from two to three weeks.

When there are no complications, such as sloughing of the feet as seen in very severe cases, the disease in cattle, sheep, and swine runs a course of from ten to twenty days.

In other animals the symptoms are somewhat the same, viz., vesicles followed by ulcerations either on the feet or in the mouth; but other domestic animals do not seem to be very susceptible. The horse shows lesions in the mouth, but only as a result of licking infected cattle or drinking or eating from buckets or troughs which diseased creatures have used. Dogs, cats, and rabbits may have the disease, but it is said to be infrequent, and, in the dog and cat, is the result of their being kept in the stable with infected ruminants or swine, or of their drinking milk from cows with udder lesions.

It is said to be rare in poultry and birds; when it occurs there may be vesicles or sores on the feet and legs, or in the mouth and upon the comb.

Hoof-and-mouth disease may occur in the human family. Among adults, attendants of cattle, veterinary surgeons, butchers, and drovers are most exposed. It may be acquired from diseased animals, and occasionally it is possible for one person to infect another. Among infants it may be caused by drinking uncooked milk from cows having the vesicles of epizootic aphtha on the udder; it is also said that fresh butter, fresh cheese, and whey can convey the germs of the disease.

The period of incubation is quite short, especially when conveyed by milk, in which case it is only from twelve to twenty-four hours before symptoms appear.

In infants the disease is not infrequently fatal. The symptoms consist of fever, headache or dizziness, conjunctivitis, an eruption on the face or around the mouth, and vesicles in the mouth, and among milkers there may be sores on the tips of the fingers around the finger nails (there may even be sloughing of the nails), or in the spaces between the fingers. When vesicles develop in the pharynx they cause great difficulty in swallowing; there may also be vomiting and diarrhœa when the infection takes place through milk, and in the case of infants and small children the disease may then end in death. Recovery usually takes place in ten or twelve days. Among animals it is said that one attack does not always secure immunity from another. Meat from animals suffering with epizootic aphtha has never been found to be infectious.

Etiology.—Hoof-and-mouth disease is undoubtedly a germ disease—both clinical and experimental evidence indicate this,—but the specific organism which produces it remains to be discovered. There are other diseases which we believe to be due to a microscopic organism of some description—such, for example, as rabies, smallpox, and cowpox,—in which the organism is so minute or so difficult to stain or cultivate that it has hitherto not been demonstrated, and the bacterium of epizootic aphtha is unquestionably one of this character. Nosotti, Klein, Schottelius, and Kurth have studied micro-organisms found in connection with the lesions of hoof-and-mouth disease, but it does not seem that the true specific cause has yet been discovered.

The vitality of the virus is not considered to be usually very great. Walley says that as a rule the danger ceases at the end of thirty days after the recovery of the last animal, but instances are given in which troughs, hayracks, and stables have caused fresh outbreaks after the lapse of several months. Therefore, in taking steps for the eradication of the disease, thorough disinfection of stables and utensils, with destruction of all litter and manure, cannot be too strictly enforced.

The post-mortem conditions found in animals suffering from hoof-and-mouth disease—in addition to the lesions in the mouth and around the feet, and eruptions on the udder previously mentioned—consist of an inflammation of the stomach and intestines, with perhaps erosions of these organs. Especially is this the case in infants, pigs, and calves infected by the use of milk from diseased cows.

The medicinal care of hoof-and-mouth disease consists in treating the symptoms as they occur, by the use of antiseptic washes, and by the application of dusting powders to the ulcerations. The food should be soft and of an easily digested character. Large flocks of sheep, where it is impossible to attend to each individual case, are sometimes treated, when the foot lesions predominate, by driving the entire flock daily through a long wooden trough containing some antiseptic drying powder.

Hoof-and-mouth disease may be confounded with other diseases if care is not exercised in making a diagnosis, such as foot root in cattle or sheep, cowpox, and poisoning with corrosive agents.

In 1884 there was an enzootic of ergot poisoning among cattle in Kansas which was mistaken at first for an outbreak of hoof-and-mouth disease (*vide* first annual report of the United States Bureau of Animal Industry, 1884).

The horse suffers at times from a contagious stomatitis which is known as *stomatitis pustulosa contagiosa*, and which has been mistaken for epizootic aphtha. This disease is not rare in the Eastern United States, while hoof-and-mouth disease, it must be remembered, does not exist on this continent. The contagious stomatitis of the horse is readily communicated from one to another, but is not serious and soon disappears from a stable. It is characterized by the formation, inside the cheeks and lips, of numerous little vesicles which break in a few days, leaving small superficial ulcers which soon heal.

More extended information on hoof-and-mouth disease may be obtained by referring to the first edition of the Reference Handbook of the Medical Sciences, Walley's "Four Bovine Scourges," Fleming's "Veterinary Science and Police," Williams' "Theory and Practice of Veterinary Medicine," Hayes' translation of Friedberger and Fröhner's "Veterinary Pathology," and the annual reports of the United States Bureau of Animal Industry. *Austin Peters.*

HOPS.—Humulus Lupulus. The carefully dried strobiles of *Humulus Lupulus* L. (fam. *Moraceæ* [" *Urticaceæ*," U. S. P.]), bearing the whole of their natural glandular coating. The hop vine is a twining perennial, with a thick-branched root, from which several long, slender, herbaceous, but tough and rough hairy cylindrical stems arise.

Description.—Ovoid-cylindrical, about 3 cm. (a little more than an inch) long, consisting of a thin, hairy, flexuous rachis and many obliquely ovate, blunt, membranaceous, rigid, glandular scales, which are parallel-veined below, reticulately veined above and each bearing a globoidal akene near the base; color of scales yellowish-green to greenish pale-brown, free from reddish or brown spots; odor strongly and peculiarly aromatic; taste bitter, pungently aromatic, slightly astringent.

Since the glandular coating (*Lupulin*) referred to in the definition contains the most of the active constituents, it should be present in normal amount, but much of the hops of the market have been deprived of a part of it by abrasion. Such hops are apt to be much broken, and are commonly pressed into cakes to conceal this appearance.

Good hops should be not much broken, and fresh. They are then of a rich, slightly yellowish or brownish green. When distinctly brown and dull, and especially shrivelled, they are stale and their composition is not the same.

The hop is a native of the temperate parts of the Old World—Europe and Asia—and grows in many places in the United States apparently wild, but probably introduced. It has been cultivated since the middle ages in Europe, and is now grown in nearly all temperate countries. England and the United States produce it abundantly, and of excellent quality.

The medicinal consumption of hops is comparatively small, and an unimportant item of the immense demand for them, mainly for flavoring ales and beers, which consumes many millions of pounds annually.

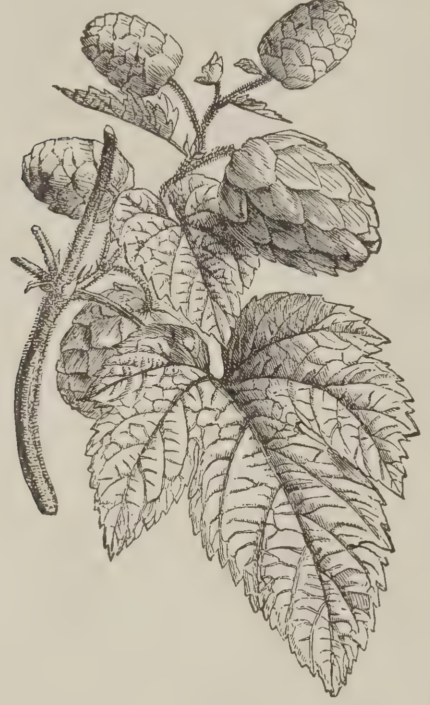


FIG. 2706.—Hop Plant in Fruit. (Baillon.)

COMPOSITION.—The entire hop, that is, inclusive of the *lupulin*, contains the following substances: Nearly one per cent. of volatile oil, of a greenish-yellow color, becoming brownish with age, and of a specific gravity of .855 to .880. It becomes at least partly converted into isovaleric acid. A very small amount of the intensely bitter *lupamaric acid* ($C_{25}H_{35}O_4$), which is soluble in alcohol or a mixture of alcohol and water. Resin, up to fifteen or eighteen per cent.; tannin two to four per cent. Small amounts of asparagin and cholin. Not more than ten per cent. of ash is allowable upon incineration. According to their staleness, more or less *phlobaphene* may be present, at the expense of the disappearing tannin.

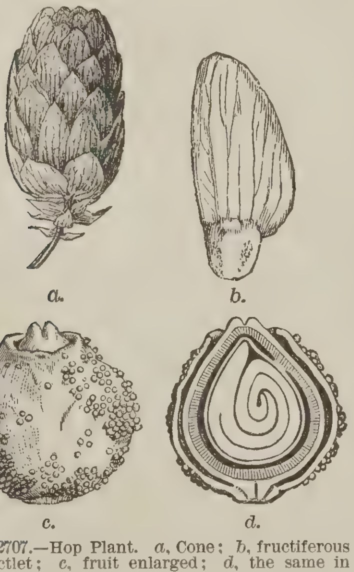


FIG. 2707.—Hop Plant. *a*, Cone; *b*, fructiferous bractlet; *c*, fruit enlarged; *d*, the same in longitudinal section.

ACTION AND USE.—Although used in many diseases with asserted benefit, but little can be said of hops more than that they are a mild bitter tonic and (especially lupulin) a feeble hypnotic and antispasmodic. In infusion they allay the pain and spasm of vesical catarrh, and improve the appetite and digestion. As an ingredient of beers they add a tonic, and perhaps diuretic, effect to that of the alcohol in those beverages. The dose is 1 to 4 gm. (gr. xv.–lx.). The Pharmacopœia provides, besides lupulin and its preparations, a twenty-per-cent. tincture, the dose of which is 4 to 8 c.c. (fl ʒ i.–ij.) and which is probably the best form of administration.

Henry H. Rusby.

HOREHOUND.—MARRUBIUM. "The dried leaves and tops of *Marrubium vulgare* L. (fam. *Labiatæ*)" (U.S. P.), but will probably be dropped from the next edition.

DESCRIPTION.—Leaves opposite, exstipulate, shortly and broadly petioled, the blades 2 to 4 cm. (1 to 1½ in.) long, roundish-ovate, truncate or subcordate at the base, obtuse, strongly rugose-veiny, more or less white-hairy, especially underneath; stems quadrangular, densely white-hairy; flowers in dense, axillary, white-wooly whorls; calyx tubular, five- to ten-nerved, with ten almost equal, erect-spreading, pungent teeth; corolla whitish, bilabiate; stamens didynamous; fruit of four ovoid, obtuse, smooth nutlets; aromatic and bitter.

A spurious marrubium is sometimes sold, having leaves of about half the size, thinner, less rugose and five of the calyx teeth much smaller or wanting.

Horehound is a European herb which has been introduced into this country, and in many places has escaped from old-fashioned country gardens to meadows and moist waste-places. Its woolly aspect and bitter odor and taste, combined with its characteristic labiate flowers and quadrangular stems, make it easily recognizable. It is also a native of Western Asia and Northern Africa.

The use of horehound dates from the ancient Romans, or even farther back. It has been a popular febrifuge and aromatic bitter tonic in many countries. The leaves and tops of the plant should be collected for use when it is in full bloom, and before the former have become old and dry; they are dried without heat, and should be preserved in dry boxes or drawers.

The most important constituent is the crystalline, neutral, bitter substance, *marrubiin*. There are, besides, a little *resin*, a little *essential oil*, *tannin*, and a considerable amount of alkaline and earthy salts.

Horehound was formerly prized as a febrifuge and antispasmodic, and used in numerous obscure diseases (hepatic, uterine, etc.), and in intermittent fever. It was also used for the only conditions for which it can be said to have any value, and for which it is still a little employed, viz., dyspepsia and debility. When a stomachic and bitter tonic is indicated, a tablespoonful or two (15 to 30 gm. = ℥ ss. ad ℥ i.) of an infusion, made in the usual way, strength one-tenth, is a tonic dose.

W. P. Bolles.

HORN'S SPRING.—Wilson County, Tennessee.

POST-OFFICE.—Lebanon. Hotel.

ACCESS.—Viâ Nashville, Chattanooga and St. Louis, or Nashville and Knoxville Railroad, to Lebanon, thirty miles northeast of Nashville; thence five miles west to springs. Conveyances meet all trains. The location of Horn's Springs is somewhat elevated and characterized during the summer months by refreshing breezes. A comfortable new hotel has recently been built, and is kept open all the year round. The springs are eight in number. According to an analysis made by Professors Safford and Summers, of Vanderbilt University, one of the springs contains the following chemical ingredients:

Calcium carbonate.
Magnesium carbonate.
Iron carbonate.
Potassium carbonate.
Sodium sulphate.
Magnesium sulphate.
Calcium sulphate.
Sodium chloride.
Phosphoric acid.
Silicic acid.
Carbonic acid.
Sulphureted hydrogen.
Organic matter (trace).

This may be taken as a type of all the springs, which, as we are informed, contain much iron and have decidedly purgative effects, resembling to some extent the water of the Crab Orchard Springs of Kentucky. The waters of Horn's Springs have an extensive reputation in Tennessee, and the contents show that they may be useful in conditions of the system requiring an alkaline regimen, a ferruginous tonic, or a mildly stimulating cathartic.

James K. Crook.

HORSERADISH.—Armoracia. The root of *Roripa Armoracia* (L.) Hitchcock (*Cochlearia Armoracia* L., *Nasturtium Armoracia* Fries., fam. *Cruciferæ*). As a drug, the fresh root is always understood, and is official in the British Pharmacopœia. The fresh leaves and herb are official in Germany and France. This well-known plant is a native of Eastern and Northern Europe, but it has been cultivated so long in other parts of the world that it occurs in a half wild state in many temperate countries. Its truly wild form is not known with certainty, and it does not readily perfect its seeds; but its roots are very tenacious of life, and make it, in localities favorable to its growth, difficult to eradicate.

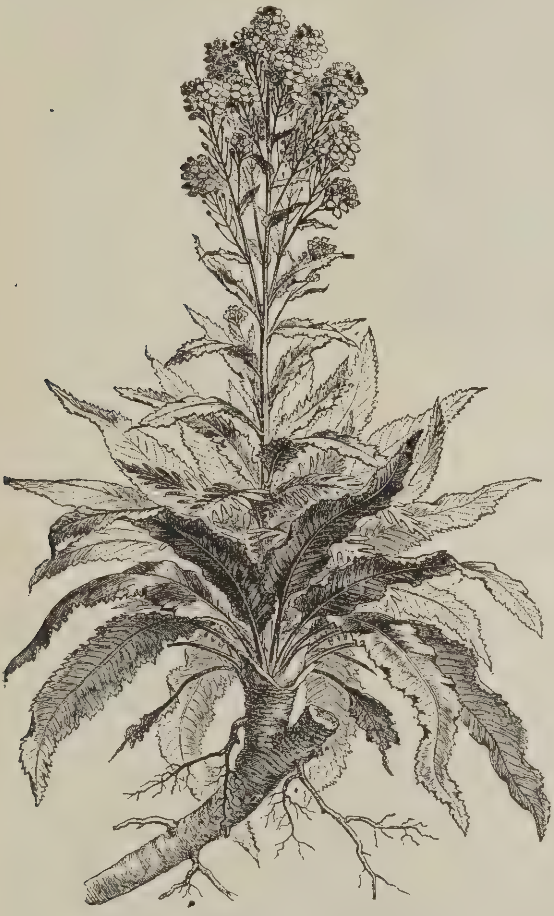


Fig. 2708.—Horseradish Plant and Root.

Horseradish root is from 1 to 3 cm. or more ($\frac{1}{2}$ to $1\frac{1}{2}$ in.) in diameter, and from 0.5 to 1 metre or more long; it is in cylindrical or slightly tapering pieces, with a large annulated and sometimes branched crown, generally broken in digging while still thick, 20 or 30 cm. from the top, but sometimes much longer and then dividing into three or four long, tapering branches, or else arising from a thick horizontal axis nearly or quite as large as the vertical one. Other pieces are of the smaller branches, or of the sucker-like horizontal portion. It is brownish-yellow outside and white within, rather too hard to be easily cut with a table-knife, but soft enough to be rapidly rasped or grated. When cut or grated, a pungent, peculiar odor is developed, which disappears upon drying or by heat; taste sharp and peppery, also disappearing with age and desiccation. Horseradish root and aconite root have more than once been stupidly confounded with each other, even with fatal result. They have no resemblance whatever excepting their pungent taste. (See *Aconite.*)

The deadly poke-root has also been fatally mistaken for horseradish.

Composition.—The root appears to contain *sinigrin* (*myronate of potassium*) and a ferment, *myrosin* (?), capable of forming with the sinigrin an oil identical with that of mustard, viz., sulphocyanide of allyl. The odor and taste of this oil are not developed until the root has been crushed or grated, or treated with water. By these means these substances, which are prevented from reacting upon each other in the whole or dry tissues, are brought together. If the root is extracted with alcohol, or if it is dried, no oil is obtained; but it can then even be produced by adding the ferment of white mustard and water. The composition is thus essentially that of black mustard. The leaves also contain a sulphureted oil said to be milder than, and not identical with, that of mustard.

Action and Use.—Essentially that of mustard, to which the reader is referred. Locally it is rubefacient, and even vesicant; internally, an aromatic and stomachic; in concentrated form, an irritant. Its long-continued use as a condiment and flavor is justified by these properties. In former times it was used in scurvy, for which it is valuable, and for gout, rheumatism, asthma, etc., for which it is useless.

Administration.—Horseradish is rarely used as a medicine in this country, but if desired as an aromatic the British compound spirit offers it in an acceptable form:

"Horseradish root, scraped	20 ounces.
Bitter orange-peel	20 ounces.
Nutmeg	$\frac{1}{2}$ ounce.
Proof spirit	1 gallon.
Water	3 pints.

"Mix and distil a gallon. Dose, 1 to 2 fluidrachms."

W. P. Bolles.

HOSPITAL SHIPS OF THE UNITED STATES ARMY.—It was appreciated very early in the spring of 1898, by the Medical Department of the Army, in anticipation of the casualties to be expected in the war with Spain, that provision must be made for moving the sick and disabled at sea.

Of the many ships chartered or purchased for the transport service of the army none was considered suitable for hospital purposes.

On April 15th, 1898, the Surgeon-General of the Army applied for a ship to be used as a hospital ship. After many vessels had been inspected, cattle ships, transports, and others, he recommended the purchase of the *John Englis* as being a suitable vessel for the purpose in view. It was his intention to fit her up as a floating hospital for the care of disabled soldiers at any point on the Cuban coast, to transport them to our own coast, and to serve as a medical supply depot for troops in the field.

By direction of the President, after considerable delay, the vessel was purchased for this purpose, and was turned over to the Quartermaster Department of the Army to be altered and fitted up for the service required. Many changes were found necessary and it was not until July 2d, 1898, that she sailed from New York for Cuba, named the *Relief.* This vessel was built by Roach Bros., in 1896, was owned by the Maine Steamship Company, and was in passenger service from New York to Portland, Me. She is built of steel to her main deck, her superstructure being of wood. She is 306 feet in length, 46 feet beam, 29 feet from keel to main deck, 17 feet draft, single screw, and of 13- to 16-knot speed depending on conditions. Her hull is divided by four water-tight bulkheads, she is well lighted throughout with electricity and heated by steam. In converting her into a hospital ship her superstructure was in the main the only portion taken for hospital purposes. All, or nearly all, of the staterooms were torn out of the upper and main decks, thus making wards in the fore and after parts of the ship extending across the whole vessel. Ward 1, upper deck, forward, was 68 feet long, 32 feet wide aft, and 24 feet wide forward, containing 76 beds. Ward 2, aft, on same deck, was 68 feet long, 32 feet wide forward, and 24 feet wide aft, and contained 62 beds. In the centre of this ward was a well or opening through the deck to the ward below. The midship space on this deck contained the engine and boiler enclosures, and the pantry and galley for the sick. On the port side were staterooms for nurses, messroom, water-closet, and wardmaster's rooms. On the starboard were the dispensary and rooms for the engineers, pantry, etc.

On the main deck, aft, was ward 3, containing 76 beds. This ward was 79 feet long, 28 feet wide aft, and 38 feet wide forward. On the starboard side of this ward was set off the operating-room, 24 by 12 feet. The midship space was given up to messrooms, galley, bakery, engine and boiler enclosures, office rooms, laboratory, dark room, and washrooms. Forward of this was a small ward of 30 beds for officers, 38 by 24 feet. A portion of this space was set aside and enclosed as the record office where all records, etc., were made and kept. Just forward of this ward were the quarters of the ship's medical officers, messroom, pantry, staterooms, bath, etc., and on this deck in the forecastle, the crew space.

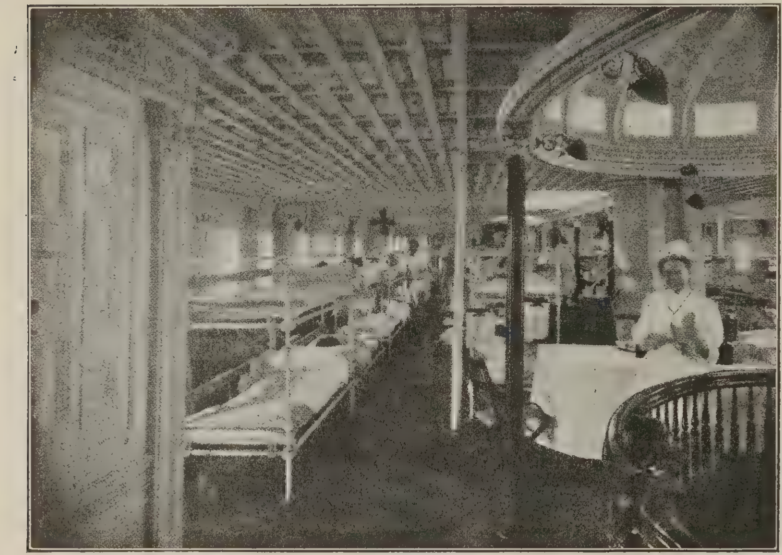


FIG. 2709.—After Ward on Upper Deck of Hospital Ship *Relief*.

On the lower deck was a ward of 46 beds aft, just forward of the "glory hole," which was given up to the ship's steward's crew. Midships were coal bunkers on either side of boiler and engine-room enclosures, store-rooms and steam laundry. Farther forward space was given up to machinery for the refrigerating plant, carbonating apparatus, disinfecting apparatus, staterooms, washrooms, and space for the crew, with elevator and steering and windlass engines.

On the orlop deck were the main store-rooms for medical, quartermaster, subsistence, and ship's stores, and bunkers for coal.

On the hurricane deck were rooms for the master and other ship's officers, eight life boats, two steam launches, and four life rafts.

The vessel was painted white with a green strake as is required by the articles of the Geneva Convention.

For her plans and general arrangements see Plate XXXII. and Figs. 2709 and 2710.

The *Missouri* was a steamship of the Atlantic Transport line, and in July, 1898, her services with her crew were offered the Government. The offer was accepted and the vessel was refitted for hospital work. She is 320 feet long, 40 feet beam, and 29 feet 6 inches in depth, and has a speed of about 11 knots. In fitting her for hospital purposes she received a steam laundry, a steam sterilizing apparatus, an ice and a carbonating plant. This outfitting may be said to have been of a temporary nature, though her equipment was excellent. After doing much good work in relieving the hospitals of Cuba and Porto Rico, and later as a floating hospital at Havana, Cuba, she was finally purchased by the Government and thoroughly overhauled for duty in the Philippines. She sailed for Manila in September, 1899, with a medical staff of four medi-

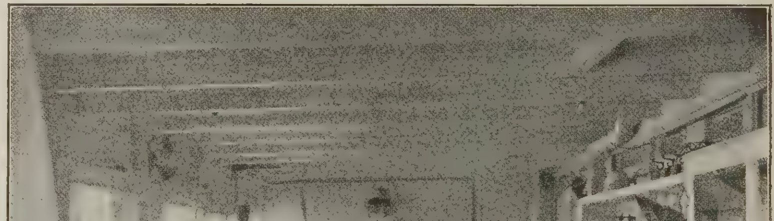
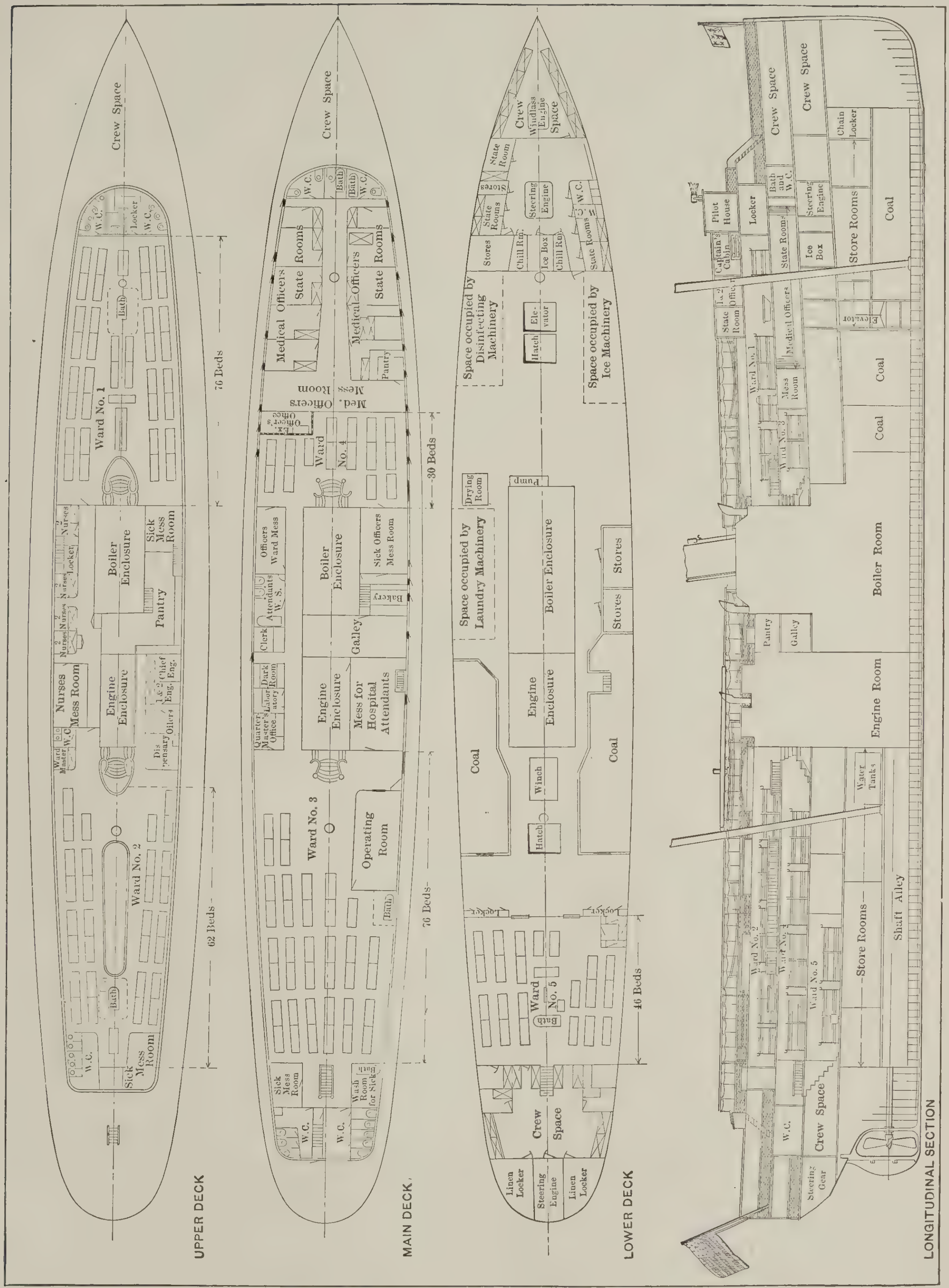


FIG. 2710.—Operating Room, Hospital Ship *Relief*.

PLATE XXXII



UNITED STATES ARMY HOSPITAL SHIP "RELIEF"

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OF THE
UNIVERSITY of ILLINOIS

cal officers, two acting assistant surgeons, two hospital stewards, seven acting hospital stewards, forty-seven privates of the hospital corps, and eleven male contract nurses. She carried large quantities of medical supplies, and officers and men as passengers for duty in the Philippines. She did good work in the islands, returned to San Francisco in the winter of 1900, and, her services being no longer needed, she was then transferred to the Quartermaster's Department for use in the transport services.

There was one other hospital ship of short life as such, during the Spanish-American War—the *Bay State,* afterward the *Aid.* She was first fitted up by the people of Massachusetts and did good work during the summer of 1898. She was purchased by the Government but was not found satisfactory for hospital-ship purposes. She was very small and unsuited for rough weather, and not long after her purchase was turned over to the Quartermaster's Department.

In the Santiago expedition the fourth divisional field hospital of the Fifth Army Corps was retained on board the steamer *Olivette,* which received patients after the battles about Santiago, and as an extemporized hospital ship did excellent and valuable work.

During the period that hospital ships were used during and following the Spanish-American War there were 8,370 admissions, distributed as follows:

Olivette: Admissions from June 14th, 1898, to August 31st, 1898, regulars and civilians, 661; volunteers, 170. Total, 831.

Missouri: Admissions from September 1st, 1898, to February 17th, 1900, regulars and civilians, 1,334; volunteers, 703. Total, 2,037.

Relief: Admissions from July 1st, 1898, to July 31st, 1901, regulars and civilians, 3,272; volunteers, 2,230. Total, 5,502.

The *Relief* sailed on her first outward voyage from New York City for Siboney, Cuba, carrying much needed supplies, arriving July 7th, 1898. She returned to New York July 23d, with 254 patients and on her second and third voyages went to Ponce, Porto Rico, returning filled with sick which she discharged at New York and Philadelphia. She then helped distribute patients from Montauk Point to hospitals in Boston and Philadelphia, and later made four more trips to Cuba and Porto Rico bringing back each time sick and convalescents to her full capacity. She was then ordered to the Philippines and after thorough repairs sailed March 3d, 1899, for Manila viâ the eastern route. She touched at Gibraltar, Port Said, Perim, Colombo, and Singapore, arriving at Manila April 12th, making the fastest time ever made between New York and Manila. She remained in Manila Bay ten weeks as a floating hospital. On June 22d she sailed for San Francisco with 250 patients, touching at Nagasaki, Yokohama, and Honolulu for coal. After arriving at San Francisco August 2d, 1899, it was decided to send her back to the Philippines for work in the islands, it having been concluded that she was not adapted to the long Pacific voyage. She continued in service as a hospital ship, taking part in the China expedition, until July 31st, 1901, when she was finally abandoned for hospital purposes and turned over to the Quartermaster's Department for use as an inter-island transport in the Philippines.

The work done by our hospital ships cannot be estimated nor appreciated by mere statistics. All cases, it may be said, did well on board. The clean, cheerful surroundings, the pure air, the good food, freedom from insects accomplished marvellous results.

The work of hospital ships properly designated as such was almost all done by the *Relief* and *Missouri.* It was the writer's fortune to serve on the former, and such knowledge as he may possess about such duty was gained by his service on that vessel. In the following discussion of the subject of Hospital Ships, he is simply giving the results of this observation and experience, and the conclusions drawn therefrom.

Paragraph 1622, Army Regulations, 1901, reads:

"Hospital transports, boats, and railway trains after being properly assigned as such, will be exclusively under the control of the Medical Department, and will not be diverted from their special purposes by orders of local or department commanders or officers of other staff corps."

It was under the provisions of this regulation that General Orders, No. 53, A. G. O., dated May 25th, 1898, was issued.

"General Orders, No. 53, Headquarters of the Army, Adjutant General's Office, Washington, May 25th, 1898. . . .

"II. By direction of the Secretary of War, the following is published for the information and guidance of all concerned:

"The steamship recently purchased for the use of the Medical Department of the Army as a hospital ship will be named the *Relief.* In accordance with the terms of the Geneva Convention the Geneva Cross flag will be carried at the fore whenever the national flag is flown, and the neutrality of the vessel will at all times be preserved.

"No guns, ammunition, or articles contraband of war, except coal or stores necessary for the movement of the vessel, shall be placed on board; nor shall the vessel be used as a transport for the carrying of despatches, officers, or men not sick or disabled, other than those belonging to the Medical Department.

"By Command of Major-General Miles:

"H. C. Corbin,
"*Adjutant General.*"

The articles of the Geneva Convention which concern the Marine are as follows:

"Art. VI. The boats which, at their own risk and peril, during and after an engagement pick up the shipwrecked or wounded, or which having picked them up, convey them on board a neutral or hospital ship, shall enjoy, until the accomplishment of their mission, the character of neutrality, as far as the circumstances of the engagement and the position of the ships engaged will permit.

"The appreciation of these circumstances is entrusted to the humanity of all the combatants. The wrecked and wounded thus picked up and saved must not serve again during the continuance of the war.

"Art. VII. The religious, medical, and hospital staff of any captured vessel are declared neutral, and, on leaving the ship, may remove the articles and surgical instruments which are their private property.

"Art. VIII. The staff designated in the preceding article must continue to fulfil their functions in the captured ship, assisting in the removal of the wounded made by the victorious party; they will then be at liberty to return to their country, in conformity with the second paragraph of the first additional article.

"The stipulations of the second additional article are applicable to the pay and allowance of the staff.

"Art. IX. The military hospital ships remain under martial law in all that concerns their stores; they become the property of the captor, but the latter must not divert them from their special appropriation during the continuance of the war.

"Art. X. Any merchant ship, to whatever nation she may belong, charged exclusively with removal of sick and wounded, is protected by neutrality; but the mere fact, noted on the ship's books, of the vessel having been visited by an enemy's cruiser, renders the sick and wounded incapable of serving during the continuance of the war. The cruiser shall even have the right of putting on board an officer to accompany the convoy, and thus verify the good faith of the operation.

"If the merchant ship also carries a cargo, her neutrality will still protect it, provided that such cargo is not of a nature to be confiscated by the belligerents.

"The belligerents retain the right to interdict neutralized vessels from all communication, and from any course which they may deem prejudicial to the secrecy of their operations. In urgent cases special conventions may be entered into between commanders-in-chief, in order to neutralize temporarily and in a special manner the vessels intended for the removal of the sick and wounded.

"Art. XI. Wounded or sick sailors and soldiers, when embarked, to whatever nation they may belong, shall be protected and taken care of by their captors.

"Their return to their own country is subject to the provisions of Article VI. of the Convention, and of the additional Article V.

"Art. XII. The distinctive flag to be used with the national flag, in order to indicate any vessel or boat which may claim the benefits of neutrality, in virtue of the principles of this Convention, is a white flag with a red cross. The belligerents may exercise in this respect any mode of verification which they may deem necessary.

"Military hospital ships shall be distinguished by being painted white outside, with green strake.

"Art. XIII. The hospital ships which are equipped at the expense of the aid societies, recognized by the governments signing this Convention, and which are furnished with a commission emanating from the sovereign, who shall have given express authority for their being fitted out and on their final departure, and that they were then appropriated solely to the purpose of their mission, shall be considered neutral, as well as the whole of their staff. They shall be recognized and protected by the belligerents.

"They shall make themselves known by hoisting, together with their national flag, the white flag with a red cross. The distinctive mark of their staff, while performing their duties, shall be an armlet of the same colors. The outer painting of these hospital ships shall be white, with red strake.

"These ships shall bear aid and assistance to the wounded and wrecked belligerents, without distinction of nationality.

"They must take care not to interfere in any way with the movements of the combatants. During and after the battle they must do their duty at their own risk and peril.

"The belligerents shall have the right of controlling and visiting them; they will be at liberty to refuse their assistance, to order them to depart, and to detain them if the exigencies of the case require such a step.

"The wounded and wrecked picked up by these ships cannot be reclaimed by either of the combatants, and they will be required not to serve during the continuance of the war.

"Art. XIV. In naval wars any strong presumption that either belligerent takes advantage of the benefits of neutrality, with any other view than the interest of the sick and wounded, gives to the other belligerent, until proof to the contrary, the right of suspending the Convention, as regards such belligerent.

"Should this presumption become a certainty, notice may be given to such belligerent that the Convention is suspended with regard to him during the whole continuance of the war.

"Art. XV. . . . (*f*) Hospital ships are required to carry the Geneva cross flag at the fore whenever the national flag is flown, and their neutrality must at all times be preserved. No guns, ammunition, or articles contraband of war, except coal or stores necessary for their movement, will be placed on board, nor should they be used as transports for carrying despatches, officers or men not sick or disabled, other than those belonging to the Medical Department."

Under existing laws and regulations the Quartermaster's Department is charged with all matters of transportation and all expenditures pertaining to the same. This department therefore makes all alterations necessary to fit the vessel for hospital purposes, and provides the necessary force to operate her at sea as a steamship. All supplies necessary for such operations, fuel, deck stores, engineers' supplies, etc., are furnished by this department. It employs a master or ship's captain and all the crew of the various departments, deck, engineer's, and steward's. These sign the ship's articles and are subject to marine laws and regulations. An officer is detailed as quartermaster on board who looks after all matters pertaining to the quartermaster's department. He submits from time to time, through the commanding officer, requisitions for supplies and repairs to maintain the efficiency of the vessel. He acts as disbursing officer and is furnished funds for the payment of the employees of his department on board and for such emergency purchases of fuel, stores, etc., as may be necessary. He also keeps on hand clothing for issue to enlisted men of the hospital corps and others who may be on duty on board, and to patients received for treatment. He should make frequent inspections of the vessel and by constant scrutiny and supervision take proper steps to keep the ship in good repair. To effect this he should consult the chiefs of the various ship's departments and require them to furnish him detailed statements of the needs of their departments which he should consolidate and carefully revise before submitting the same to the commanding officer. Except in emergencies all estimates are sent to the Superintendent of the Army Transport Service who takes proper steps to make all repairs and furnish all supplies pertaining to the Quartermaster's Department. The regulations of the Army Transport Service are followed by the quartermaster of a hospital ship in so far as they do not conflict with the regulations of the Medical Department in its management and control of the vessel as a hospital.

A hospital ship is a general hospital afloat; as such it is under the exclusive control of the Surgeon-General and is governed by such regulations as the Secretary of War may prescribe. The surgeon in charge commands and is not subject to the orders of local commanders. As commanding officer the surgeon in charge is responsible for the ship at all times. His duties as commanding officer are practically the same as those of a commanding officer of a post, and in addition he conducts and maintains the hospital department. He is responsible for the proper application and preservation of all property, for the strict enforcement of laws and regulations, and will satisfy himself that the disbursements of officers under him in charge of funds are in accordance with laws and regulations and that their accounts are correct. The commanding officer should study the regulations governing the marine and be careful to observe and conform to the laws and regulations regarding quarantine, pratique, and customs of any port the vessel may visit. For the proper navigation of the vessel he looks to the master of the ship and holds him responsible for the efficiency and discipline of the crew. He should co-operate with the quartermaster and master in all matters which tend toward the comfort, safety, and efficiency of all on board. He should require frequent fire drills and make, with the quartermaster and master, frequent inspections of all parts of the vessel.

The conducting of the various departments of the ship, deck, engineer's, and steward's departments, differs but little, if any, from the management on any steamship in passenger service.

A Commissary Department is maintained on board under the charge of an officer designated as commissary officer. The quartermaster usually acts in this capacity. There are kept on hand ample commissary supplies, not only the components of the ration, but a variety of additional stores for sale to those on board and for issue to the sick.

Early in the Spanish-American War the subsistence of those on board a hospital ship came from three different sources. First, issues of the ration to enlisted men serving on board and to the sick who did not require special diet. Second, all sick requiring special diet were subsisted by stores purchased in open market by the medical officer in charge, not to exceed sixty cents per day per man. Third, the subsistence of the ship's crew was provided by the Quartermaster's Department; an allotment was made of fifty cents per day for each man and one dollar per day for each ship's officer and placed in the quartermaster's hands for their subsistence. For convenience of administration, there was maintained on the *Relief* at this time a hospital mess only, and the ship's employees were considered as living in this mess which was maintained by the medical department. The quartermaster at the end of each month paid to the medical officer commanding the amount allotted for the subsistence of his employees, and this amount was accounted for on the hospital fund statement.

Later the subsistence of all on board was placed in the hands of the subsistence department. The employees were subsisted from supplies purchased by the commissary officer not to exceed a fixed amount; a hospital mess was maintained for enlisted men on duty and the sick, and rations were issued for all these except such of the sick as required special diet. For these an allowance of forty cents per day was made, to be expended as provided in Army Regulations, 1392, 1393, and 1395:

"Par. 1392. The medical officer in charge of a general post, or camp, hospital ship, or transport, carrying patients, is authorized to purchase, under the laws and regulations relating to purchases of subsistence stores, such articles of food, both solid and liquid, not carried in stock by the subsistence officer who issues rations to the hospital, and to call upon such subsistence officer for the issue of such quantities of articles from the stock already on hand as, in the judgment of the medical officer, are required for the diet of enlisted patients under his charge who are too sick to be subsisted on the ration as ordinarily issued; the total combined money value of the stores hereby authorized to be purchased and issued as above in any month not to exceed the rate, calculated on the month's transactions, of forty cents per man per day for those actually requiring special diet. Subsistence officers are authorized to pay all duly certified bills of purchases made by medical officers under the provisions of this paragraph, or to make the purchases themselves at the request of the medical officers, and to make issues for special diet hereunder from stores on hand at their request, provided that the rate of forty cents per man per day for those enlisted men actually requiring special diet is not exceeded in any month."

"Par. 1393. When a ration has been drawn by the hospital for an enlisted patient for a ration period and it becomes necessary during that period to put him upon special diet, due deductions will be made by the surgeon in charge on the next ration return of the hospital for the rations unused by him; and, reciprocally, when a patient on special diet has been restored in a ration period to regular diet, the necessary additions will be made on the next ration return of the hospital for the rations used by him. The object of this rule is to prevent the hospital from having the benefit of the rations of enlisted men for the period they may be put upon special diet, and to give the benefit of an issue of rations where men have been restored to regular diet when rations had not been drawn for them."

"Par. 1395. The formation of a hospital fund from articles purchased for special diet for enlisted men too sick to use the army ration, or the application of such articles to uses other than those for which intended, is prohibited. Such articles will, as far as practicable, be procured in quantities sufficient for the needs of specific patients only, and no large accumulations will be made. Nothing in this regulation will be construed to prevent the maintenance of a hospital fund from savings of the rations of the hospital corps, and the patients who do not require special diet."

The duties of quartermaster and commissary on board may satisfactorily be performed by an experienced medical officer who can otherwise materially assist the commanding officer.

The Medical Department furnishes and supplies a hospital ship the same as it would a general hospital on shore. It causes to be detailed a medical officer commanding, and medical officers to assist him in its administration. It details a suitable number of hospital stewards, privates of the hospital corps, and nurses, male or female as may be required, and employs such civilians as may be necessary as mess stewards, mess men, cabin boys, cooks, laundrymen, etc. The commanding officer has placed at his disposal funds for the payment of the employees of the department and the purchase of such medical and hospital supplies as may be necessary. For these funds he is personally accountable and must submit his accounts each month to the Treasury Department through the Surgeon-General. The ship is provided with medical supplies of every description for her own hospital needs, and stores in abundance in excess of these, for issue from time to time to shore stations, or transports, etc., where supplies may be needed.

The *Relief* was fitted up with double bunks, one above the other, with felt mattresses and woven-wire bottoms fastened to tubular bent iron frames, enamelled white. These were secured to the deck and arranged end to end lengthwise of the ward with suitable aisle spaces. Each bed was supplied with side rails of maple, about three inches wide, fastened by clips and bolts to head and foot for rolling boards. One of these was never removed; the other was used only in rough weather, being detached for convenience in handling the patient at other times. Swinging cots were not used on board, but it is believed that a certain number swung on gimbal joints would prove very satisfactory for very severe cases. Each ward had one or more bathtubs and wash basins fitted with "Gagenstrom" plumbing fixtures for both fresh and salt water, heated by steam, with shower, etc., the tubs curtained off by canvas screens suspended from the ceiling. Portable tubs on wheels were also supplied, but usually patients were carried to the ward tub when necessary. Each tub fixture was supplied with a thermometer so that the temperature of the water flowing into the tub could be accurately determined and controlled.

Directly off each ward were water-closets and urinals in sufficient number. All closets on board ship should be supplied with automatic flushing apparatus or some device to insure the security of the trap seals. In rough weather the rolling of the vessel empties out ordinary traps and permits soil-pipe odors access to the ship. Plumbing connections should be made of heavy rubber tubing in all places where the working of the ship might break the pipes. On the upper and main decks of the *Relief* were hoppers, fore and aft, with a salt-water flushing supply pipe designed to receive dejecta from bed pans, slops, refuse, etc. The outlets of these hoppers were five-inch pipes running clear of the ship outside, down to the water line. The bedding for the sick was that furnished shore hospitals, good feather and hair pillows, woollen blankets, sheets and pillow cases. An abundance of towels was supplied for all needs. The interior of the wards was painted white, touched up with gold. Each ward had many large windows by means of which fresh air and light were freely admitted. On the main deck the ward floors were kept shellacked. Floor polish was tried, but did not prove satisfactory at sea. The floors of the upper wards were the canvas-covered decks, and strips of rubber matting were used in all aisles and passageways. When the vessel first sailed her main deck was painted within and without, but paint was found to be unsatisfactory. The decks were later scraped, planed, and sand-papered; in the wards they were then treated with shellac varnish, and the outer decks were holystoned. Interlocking rubber tile floor gave excellent satisfaction in toilet, bath, and operating rooms. This comes in various designs of shapes and colors, and if well put down is easily kept clean and sanitary. On ship board when paint is used it must be frequently renewed, for chemical action is rapid both from gases of coal combustion and from the salt water. Cleansing and overhauling seem to be always necessary. Just as a satisfactory condition of cleanliness seems attained, it becomes necessary to put on coal and coal dust permeates the whole vessel. At these times windows and port holes should be kept closed to exclude all this dirt.

Each ward was supplied with a white enamelled glass and iron dressing table and a suitable outfit of instruments, dressings, and appliances for ward treatment. Each bed was numbered, had a record clip for the patient's history, charts, etc., and had a sea-can secured by its handle to the rolling board conveniently at hand for seasickness. Each ward had a small refrigerator for the keeping of such articles as required ice for preservation and to keep cool drinks and beverages for the sick. A ward table with drawers and compartments proved of great convenience as a place to keep the various articles needed in ward work.

In the ward toilet-rooms were small closets in which was kept cleaning gear, such as mops, brooms, brushes, cloths, etc., used in ward police; suitable racks were also arranged for bed pans and urinals so that they might be secure when not actually in use. Small electric diet kitchens were installed in each ward and proved valuable accessories to the central diet kitchen.

The operating room was 24 by 12 feet, on the main deck next the principal gangway. It was finished in white enamel and was fully equipped. It was supplied with an autoclave, instrument and dressing cabinets, irrigating stands, stands for bowls, bunch lights for night work, an electric transformer, formalin apparatus, etc. There was hot and cold water distilled from the condensing apparatus of the ship. Oil stoves were at first used for boiling water and preparation of instruments, but later electric stoves were supplied. The usual outfit of instruments and apparatus was furnished and modern surgical methods were strictly observed; the equipment was complete. The operating tables, two, were secured to the floor; the movements of a vessel make it necessary securely to fasten in some way all loose objects when at sea.

A wheel litter was found of service in transporting patients from wards to operating room, being more easily managed than an ordinary litter. There was installed near the operating room a fine *x*-ray apparatus. When it was placed on board it was found impracticable to put it in a dark room because of lack of space, so it was available for use only at night. It proved of great use in many cases.

Very little skiagraphy was done, but the fluoroscope was used to advantage in locating missiles or making diagnoses, and operation if indicated followed.

There was a small dark room for photographic and skiagraphic work with the necessary supplies and equipment. This room was also used for eye, ear, and throat work when necessary.

The pathological laboratory had a complete equipment and much interesting and valuable work was accomplished. While at sea it was hardly practicable to undertake more than ordinary clinical pathological work, but while serving as a floating hospital at anchor there was no limit to the investigations which might be conducted.

An ice plant, the ammonia machine of De La Vergne, was installed on board for the production of ice and for refrigeration. It produced all the ice required by all on board and kept a large chill room at proper temperature for preservation of perishable food supplies. While this machine gave excellent satisfaction, one which does not require ammonia, if equally good, would be preferred. On several occasions during overhauling and repairing the fumes of ammonia escaped to such an extent as to render that portion of the ship intolerable. A serious accident occurred on the *Bay State*, afterward the *Aid*, in which the ammonia machine exploded, killing one man and seriously injuring about a dozen others. An accident occurring to an ammonia machine while at sea, causing escape of the gas, might be followed by most disastrous results. The use of such machines is prohibited in our naval vessels, and dense air machines are used almost exclusively. It is hardly necessary to state that refrigeration will not be successfully accomplished unless great pains are taken to secure proper insulation.

Having proper refrigerating facilities, articles of food can be preserved for weeks and thus suitable diet be furnished the sick for extended periods. This is an important point and must not be overlooked in making preparation for caring for large numbers of sick at sea. The ice plant is also of value in ventilating systems for cooling when necessary air delivered to any portion of the ship. This was not done on the *Relief* which had no special ventilating system, but on our transports the ventilating system has been so arranged that air is furnished cooled by means of the refrigerating device. This system has not yet been sufficiently tried to warrant positive assertions as to its utility under the varying conditions to be met at sea. The ventilation on the *Relief* was "natural." There was no system for providing fresh nor for exhausting the vitiated air. In this respect the vessel was defective. However, her wards were all in the superstructure, extending from side to side and had numerous large windows opening on the outer deck. There were also hatches and openings in the domes of the upper wards; the lower ward, aft, opened into the ward above by a large well, an oval opening, above which were hatches on the hurricane deck which were always kept open. In bad weather when windows, doors, and hatches had to be closed the air was very poor, but fortunately it was nearly always practicable to have openings on the leeward side of the vessel. In the lower decks the air was never as good as it should have been. Small port-hole openings existed and in good weather the large cargo ports were kept open, but in bad weather the ventilation was very unsatisfactory. Much fresh air reached this portion of the ship by means of ventilating cowls on the upper deck which conducted fresh air down to the boiler and engine rooms. But this was totally inadequate. In tropical waters and in good weather when everything could be kept open there was but little fault to be found, but in stormy weather it was different. The system of ventilating adopted on our transports could very properly be installed on our hospital ships, as was done in the case of the *Missouri*. This system is worked by two sets of fans, one forward, another aft, on the spar deck, with metal air ducts leading to all berth decks. These fans are either intake or exhaust, as may be required, and deliver air at the outside temperature or warmed, cooled, or filtered, according to the needs of the situation. The rated capacity of each fan is 25,000 cubic feet of air per minute. There is an air-cleansing and cooling device attached to the fan through which when tested the air current passed at a velocity of 1,000 feet per minute with a discharge velocity at the farthermost point from the fan in the lower troop deck of 950 feet per minute. Such a system, or one similar, should be placed in all hospital ships and fresh air carried to every compartment and store-room in the vessel.

A carbonating apparatus fully equipped was installed on board the *Relief* when the vessel was fitted out and gave great satisfaction. Large quantities of carbonated water were sent ashore in Cuba and Porto Rico in ordinary bottles; that for ship's consumption was put up in siphon bottles. The distilled water made on board was charged at but trifling expense. All effervescing drinks are grateful to patients at sea, and this carbonated water with fruit juices, or without, was in great demand. The ice plant and carbonating plant were on the main deck and were operated, as were all appliances or machinery requiring steam, by the engineer's department. On this deck was installed a disinfecting and laundry plant. The former was a large Kinyoun steam sterilizing or disinfecting apparatus so arranged that formaldehyde could be used as well as steam. An apparatus of this kind seems essential and a desirable portion of the equipment. Many days or months may elapse when it is of no use, but when receiving patients from an infected district it performs an important service in assisting us to prevent access of disease to ship board through patients' effects. The laundry was equipped with a washer, a rotary dryer, mangle, and other appliances necessary in a place of this kind, and an ample drying room. Its operation on ship board was sometimes subject to interruption at sea owing to lack of fresh water, but in port at all times plenty of fresh water could be procured and no difficulty was experienced in cleaning the bed and table linen of the whole ship. The situation of the laundry on the *Relief* was an objectionable one. It was adjoining the boiler room and difficulty was experienced in excluding coal dust and smoke which soiled the clothes and made the work unsatisfactory. A location should be secured where such annoyances could be avoided. With competent laundrymen it would seem that all laundry work might be done in a laundry of this kind, but as a matter of fact only the work above mentioned was performed satisfactorily. All pieces requiring hand work could not be done satisfactorily; the reason for this was because of inadequate water and facilities for rinsing, starching, and the subsequent handling of the clothes in a place free from dust. Two civilian laundrymen were employed and three men of the hospital corps detailed for operating the laundry. A hospital steward was given general charge and kept check of the clothing passing to and from it.

The lowermost deck of the ship was given up to storerooms. Of these there were many, for all the various departments of the ship must have abundance of supplies for long voyages; the commissary department needs room for thousands of rations and special articles; the quartermaster suitable room for clothing and equipage, and the medical department much room for the great variety of supplies it must necessarily have in readiness. All these stores must be placed with due regards to space, convenience of handling, and accessibility and security. When the articles can be so arranged, their disposition should be by some system, alphabetical or supply table lists, so that account of stock may be readily taken or articles easily located when needed. A separate strong room should be used for all liquors, well secured by proper locks; this will preserve the liquor and trouble will not arise among members of the crew because of whiskey on board coming from sources unknown.

Bedding and clothing not in use should be frequently taken on deck and aired. All store-rooms should be often inspected and contents verified from time to time by a commissioned officer. All stores should be replenished when necessary by proper requisition, the responsible officer bearing in mind that he will be held accountable for any suffering which may result from his failure to ask for supplies when it is evident that they will be needed.

Fresh-water tanks should be provided so that an ample supply of fresh water may always be available. Instead of putting in quantities of iron for ballast it would have been much better on the *Relief* had she had more tanks to take additional amounts of fresh water for ballast. All water used for cooking, drinking purposes, and for the sick on board was distilled or made in the ship's condensers. This was aerated by a fresh-air intake pipe coming from the upper deck near the pilot house, and this water was also filtered before being used.

The equipment of the ship for fire in addition to life rafts, boats and life preservers, included fire plugs and fire hose and in all store-rooms hand grenades.

Deck chairs were furnished in abundance for patients and all others which when not in use were stowed in racks provided to secure them. A well-selected medical library was furnished by the Medical Department, manuals of reference by the Adjutant General's office, and a good library of about five hundred volumes of history, biography, travel and fiction was presented to the vessel by interested people of New York City. This library, a fine music box, and an Æolian, also gifts, furnished much entertainment to convalescents and added materially to the comfort and contentment of all.

A hospital ship should have dynamos of sufficient capacity to operate a lighting system, searchlights, electric fans, and electric heaters in ample quantity for all needs. Two such dynamos should be installed, each of sufficient capacity to meet all requirements, so that while one is in use the other may be receiving such repairs as may be required; with two one may be available at all times, with only one there would be times when light would be wanting. A competent electrician should be employed on board to attend to the electric appliances.

The *Relief* was well equipped in this way, though at times the dynamos proved of insufficient capacity to meet all requirements. Electric fans were placed in every portion of the vessel and were of material value in ventilation and of great comfort to all when the vessel was in tropical waters. When we consider the management of the hospital ship for hospital purposes it is found to be essentially the same as that of a shore hospital. We have our medical officers, our hospital corps detachment and nurses, and such civilian employees as may be necessary. The hospital force of the *Relief* at first consisted of a commanding officer and six other medical officers. There were three hospital stewards and twenty-nine privates of the hospital corps, ten graduate male nurses and ten graduate female nurses. Experience caused some modification in these numbers. The male nurses were dispensed with and more hospital corps men detailed and the number of women nurses reduced to eight. At times when at sea the efficiency of our working force was much reduced because of seasickness, for but few of all our staff had ever had sea duty before.

The duties of the medical officer commanding have already been partially outlined: in the hospital department he assigns his assistants to various duties and has charge of the general administration of everything concerning the welfare of the sick. One medical officer he selects as his executive officer, usually the next in rank, to aid him in his supervision. His duties are practically those of an adjutant to a commanding officer; he has charge of the office and records and sees to the details of men for special duty; the keeping of the clothing accounts of men on duty and patients under treatment rests with him and he should supervise the preparation of all regular reports, promulgate all orders, and conduct the general correspondence. He distributes patients received for treatment, and generally looks after the welfare of the patients and management of the hospital as an aid to his superior. It is not necessary that an executive should perform these duties; the commanding officer may be his own executive either in whole or part, and indicate to his assistant such duties as he desires him to perform; but the performance of the duties by an executive as outlined will relieve the commanding officer of many details and much routine work.

There should be assigned to each ward one medical officer, or if the number of patients or the character of the diseases or injuries warrant it, then more than one. All serious cases should be reported by the ward medical officer to the executive or commanding officer and consultation held as to treatment, surgical or medical. A roster should be kept, and at all times there should be a medical officer of the day. He is always on duty ready to respond to any calls in the wards at night; he should have a sick call every morning for the enlisted men and employees on board if some officer is not regularly designated to look after these, which is perhaps the better plan. When any one of these employees is excused from duty because of sickness he should be shown on the morning sick report and properly reported on the reports of sick and wounded.

Of the hospital corps detachment there is required one hospital steward in charge of records in the office; one in charge of property and returns pertaining thereto; one in charge of the general police of those portions of the ship occupied by the medical department. There should be an acting hospital steward in charge of the dispensary, one in charge of the laundry, and one in charge of each ward. The steward in charge of general police should have charge of patients' effects. With these non-commissioned officers, though more could be utilized, the work of ships of the capacity of the *Relief*, 250 patients, can be very well managed. There should be for this number about forty privates of the hospital corps; six on duty in each ward of fifty men, one as assistant in the dispensary, three in the laundry, two in the operating room, one in the office, and the others for special duty in various capacities, as clerks, diet assistants, etc. Regular instruction should be given these men for at least twenty hours per month as prescribed by Army Regulations; they should be well disciplined and every effort made to maintain the high efficiency required at the present time for men of the hospital corps. Frequent inspections should be held and each man's clothing and equipment seen to be in proper condition. Men on ship-board duty need not be furnished the ordnance equipment issued men of the corps on shore duty; they have no possible use for anything but the belt and waist belt plate. Other articles of ordnance should be kept in the general store-rooms for issue when men are detached and sent for duty ashore. The hospital corps pouch is also an unnecessary incumbrance on ship board and there is no necessity for its issue to the men; it too should be kept in the general store-rooms. Each man of the detachment should have a barrack bag to hang on his bunk and a stationary locker for storing and securing his clothing and personal effects. All boxes and trunks should be kept below in the trunk rooms. Certain days should be established as trunk days when the men may have access to their boxes and belongings for such articles as they may not be allowed to retain in locker and bag. It is impracticable for them to display their shoes under their bunks, and their other equipments upon them as is customary for inspections in shore hospitals; the movements of the ship will not permit. The duties of members of the hospital corps on sea duty differ but little, if any, from the requirements on shore. The Army Hospital Corps is discussed in another portion of THE HANDBOOK to which reference may be made for full particulars on this subject.

Women nurses did excellent service on board the *Relief*, beginning when the vessel first sailed and continuing up to the winter of 1899–1900 when their service was discontinued. At first ten nurses were on duty, but later it was found that eight were all that could be satisfactorily employed. No night duty was required except in special cases. Two nurses were assigned to each of the three larger wards, one to the officers' ward, and one in charge of the operating room and the diet room. They were employed under contract and later under the regulations governing the nurse corps. Considerable friction existed at times between these nurses and the members of the hospital corps in regard to division of duties and responsibility, and much tact was required to get the best services from both. The men disliked the idea of being subjected to the authority of a woman nurse in all matters; it was finally arranged that the nurse in the ward should be responsible for the nursing proper, and the acting hospital steward in charge be responsible for the discipline and police, the two to consult together in all matters pertaining to the welfare of the sick in the ward. By this arrangement the ward work was in most cases satisfactorily performed. Divided responsibility, however, is always unsatisfactory and best results cannot be thus attained. With good hospital-corps men as nurses it is believed that the place for women nurses is not on board hospital ships. Their presence requires separate arrangements for sleeping apartments, toilet, and mess rooms, which in the cramped conditions found on ship board works at times disadvantageously. The *Missouri* employed no female nurses, but instead had graduate male nurses whose services were reported satisfactory.

Ten male nurses were at first employed on the *Relief*, but they were relieved after the first voyage and additional hospital-corps men secured. There was constant friction between them and the women nurses and the hospital-corps men, and it seemed best to dispense with the male nurses. Some of these afterward enlisted for service on board and gave excellent service when they understood the requirements as to discipline demanded of enlisted men.

All the cooking on the *Relief* was performed in one small galley. This arrangement was most unsatisfactory, but the plan of the ship did not admit of more galleys. Had it been practicable there should have been at least a galley for the sick and hospital-corps detachment and employees drawing a ration, and another for the ship's crew and officers. This arrangement is suggested because of the sources of the food supplies or subsistence. The sick if not requiring special diet, all the enlisted force and rationed employees are subsisted on the ration, but the others above mentioned are subsisted by the commissary department on such articles of food as may be required, not to exceed a certain fixed per-diem value. It thus becomes necessary to know just the value of the foods consumed by the latter class, that the authorized allowance may not be exceeded. The management of the ration is the same on hospital ships as in shore hospitals. Savings can be made and a fund established to purchase such additional articles as may be desired. Those of the sick requiring special diet are supplied as noted in the beginning of this article from a special forty-cent subsistence fund in lieu of the ration.

The conditions on shipboard differ so much from those ashore that it is economy to employ a competent experienced man as ship's steward and a suitable number of employees as mess men, cooks, pantry men, cabin boys, etc., to constitute the steward's department. This department should be conducted as is done on large passenger steamships, and subdivided under as many assistant stewards as may be required to conduct the separate messes. A mess room should be provided for the hospital-corps detachments, but experience seems to indicate that the sick may be better served by individual service on trays. If the ship be commodious it might be practicable to have mess rooms for the convalescents, but in actual practice on the *Relief* it was found more satisfactory to give each patient, whether up and about or confined to his bed, his meals served on a tray. This tray was prepared at a diet kitchen on the upper deck situated just over the ship's galley from which the cooked food was sent on dumb-waiters. This diet kitchen had numerous steam-heated warming tables where the food was kept hot during its preparation for the tray. This room also had several boilers for making coffee, bouillon, chocolate, and other liquid foods; ample drawer and shelf space was here provided for dishes and cutlery. At mealtime the special diet patients requiring food in bed were first served, then those on the regular diet; each convalescent able to report for his tray came for it at the diet room and passed on to his bunk or any suitable place adjoining to eat his food. Meals were served to one ward at a time; convalescents, when able, assisted the attendants in the distribution of the trays. The soiled dishes were returned for cleansing to the diet room at another window. A nurse was always on duty when the meals were being given out and superintended the arrangement of the trays to make them as inviting as possible. She received lists from each ward showing the number and kind of diets required, supervised their preparation, and kept check on the issues. Japanned trays were first used but were not desirable; they soon became corroded and of unsightly appearance: heavy china dishes and plated silver ware were used. Dishes required constant replenishing owing to frequent accidents. It would be economy to use white enamelled ware for all dishes and trays. It is open to the objection of chipping but is very durable. The main diet kitchen requires an ample force of attendants to facilitate rapid handling and serving of food that it may reach the patient in a palatable condition.

Little supplementary electric diet kitchens in each ward are of great convenience in preparing foods and hot drinks outside of regular meal hours.

The galley had a fixed range, boilers for steam cooking, shelves, racks, etc., for cooking utensils. Adjoining the galley was a bake-shop; the butcher-shop was in a small room next the cold-storage room on the lower deck.

In receiving patients on board a hospital ship it is oftentimes necessary to send ashore the ship's boats for transporting the sick to the ship. Each of these boats will accommodate four patients on litters or about twenty if they are able to sit up. When thus loaded the boats are towed by steam launches, it being impracticable to row when they contain patients. One launch can tow a string of three or four boats and patients can be taken on board very rapidly. Litter squads are detailed as loading parties to accompany the boats; others remain on board and unload and distribute the patients when received. If the ship's construction will permit it much labor may be saved by rigging up block and tackle and lifting the patient on the litter to the deck by means of the steam windlass. The construction of the *Relief* prevented such an arrangement and all patients were received on board by gangways. Of these there were two; they were especially constructed, were broad and long so that when lowered the incline was gradual. The small boat drew alongside, the bearers made ready, and at a propitious moment when the boat was on the crest of a wave or swell, passed the patient over to the other bearers waiting on the gangplank to receive him. In rough weather loading was difficult and at times had to be suspended. The bearers learned to be very expert, and in all the hundreds of patients handled there was never an accident, though at times the up-and-down play of the small boats at the gangway was many feet. The patient was carried up to the main deck and assigned to a suitable ward. Stimulants and hot foods were in readiness when needed. If the condition of the patient would permit he would be given a tub bath; if not, then a sponge bath in bed, and given fresh hospital clothing. His valuables were properly listed and cared for by an officer assigned to such responsibilities. Such of his clothes and such toilet articles as he might have or need might be left in his clothing bag hanging at his bunk. All other clothing was placed in bags designed for patients' effects. These bags were made of strong bed ticking with draw string, and were about three by two feet in dimensions. They were furnished by the medical department and their expenditure was authorized; in other words, they were expendable. Shipping tags were provided and each man's bag had tied to it a tag giving his name and military address, his ward and bed number. These bags were placed in store-rooms so arranged that the tags were exposed, the arrangements being made by wards to facilitate accessibility. Such property as he might have which could not be put in bags—trunks, chests, etc.; volunteers will have quantities of such,—were tagged and put in the trunk room. When the patient was transferred ordinarily he was given the bag which bore his name on the tag and identified it as his in his further movements. If too sick to take charge of it himself, it was simply turned over to some responsible person representing the authority of the hospital to which he was destined. This system was very satisfactory and after it was devised but little trouble was experienced with patients' effects which prior to that time had given rise to an endless amount of trouble and confusion. On the *Missouri* a checking system was devised in which the bag was checked and a duplicate issued for the patient. It proved satisfactory, it is believed, to the authorities on board the *Missouri*, but it is not considered to be as well adapted to the needs of hospital ship service as the method used on the *Relief*. A patient received on board should be accompanied by a transfer slip giving his medical history and a descriptive list. When he is discharged the hospital his new commanding officer should be informed as to his accounts. Great care must be taken to keep proper accounts for each man while on board. The regulations governing muster, payments, issues of clothing, and all matters pertaining to administration must be strictly observed.

The dead should be buried at sea or properly embalmed and placed in metallic caskets; the former is to be preferred, but it is customary as a matter of sentiment to do the latter.

In the past sick and wounded have been moved by boat whenever the seat of war made it feasible to resort to water transportation. Steamers have been used on navigable rivers and sailing vessels and steamers on lakes and the ocean; in some instances canal boats have been utilized when battles have been in localities where canals existed: they were used after the fight at Balls Bluff during the Civil War, and the British have used them in Egypt. Small boats, barges, etc., may at times prove useful in emergency, but their discussion hardly comes within the limits of this article where the hospital ship proper is the subject under consideration.

England seems to have been first in preparing floating hospitals and transports for the sick, but there seems to be very little record of any systematic preparation previous to the Crimean campaign of 1854. During this campaign a fleet of "well-appointed" steamers, the *Orient, Poistiers, St. Hilda, Clifton, William Jackson* and others, carried in twenty-two months 114,668 patients. In 1858 the British fitted up two hospital steamers, *Mauritius* and *Melbourne*, for the use of their forces in China. In the former the lower troop deck was fitted up for the sick and wounded with berths ranging fore and aft. Heat was supplied by the engine-room and by swinging and cabin stoves, and ventilation secured by hatchways, port-holes, and tubes arranged from the galley fires. One thousand gallons of fresh water were supplied daily from the condensers. The *Melbourne* was in a general way fitted similarly to the *Mauritius*. Each had a surgery 15 by 10 feet, and a dispensary. The berths were 6 feet 3 inches by 2 feet 6 inches, with metal bottoms; good bedding and table furniture and good diet were provided. Each steamer had wash-rooms, washing or laundry rooms, and the usual butcher room, bake-shop, and store-rooms. In fitting up it seems to have been intended that these steamers should be used exclusively as hospital transports.

In 1873 England converted the line-of-battle ship *Victor Emmanuel*, a wooden, screw steamer, 5,157 tons, 2,414 horse-power, into a hospital ship and transport for service on the Cape Coast, Africa. The alterations were made at a cost of about $200,000, and accommodations were provided for 142 patients, with an additional capacity on deck for from 60 to 80 convalescents. Fifty-five men were detailed for hospital service on this ship: 16 non-commissioned officers and 39 privates; in actual service at Cape Coast more aid was required. In addition to these there were men employed for general purposes, as bakers, cooks, etc. Reference to Figs. 1192–1195, in Vol. III. of the former edition of this HANDBOOK, will show the arrangement of this vessel.

Spain fitted up two ships for hospital transports in her struggle with San Domingo. These are said to have done good service, but no detailed description of them can be obtained.

The United States used no special boats for the sick in the war with Mexico, 1846–1848, and early in the Civil War the disabled were transported on the ordinary passenger steamboats of the Western rivers. Later these were fitted up as hospital boats, but little alteration being required to make them well adapted for hospital service; they usually had large well-lighted and well-ventilated cabins, and the removal of the thin partitions between staterooms made other wards or rooms suitable to accommodate patients. Col. Joseph R. Smith, to whose writings the writer is indebted for this brief historical review, states that he found records showing that more than 100,000 patients were carried on hospital boats during the Civil War. Of these a great number were carried on the river steamer *D. A. January*, which in forty months handled 23,738 patients. This boat was 230 feet long and 65 feet wide. Its ordinary capacity was considered about 400, though it carried as many as 554 patients.

The hospital steamer *City of Memphis* was 330 feet long and 70 wide and carried comfortably 750 wounded. The *Empress* was 266 feet long and 45 wide, with an ordinary capacity of 500 patients, though she at one time carried

817. These vessels on the rivers frequently passed towns and landing places where supplies could be obtained and did not require the same equipment and stores as are needed for sea-going vessels. In addition to wards each of these vessels had rooms for officers and attendants, store-rooms of various kinds, kitchen and special diet kitchens, pantries, dumbwaiters, linen rooms, dispensary, operating room, bath, water-closets, etc. Water was supplied from a refrigerating apparatus by faucet in convenient places. Medical officers, hospital stewards, ward masters, and nurses were detailed in sufficient numbers. The medical officer or surgeon-in-chief was in absolute control and responsible for the administration. Figs. 1196–1199, in Vol. III. of the former edition of this Handbook, show the arrangement of these boats, the *January* being taken as a type.

In May, 1862, the Medical Director of the Army of the Potomac asked for hospital steamers sufficient to carry 5,000 patients; from this time water transportation was recognized as a method of moving the disabled and a medical officer was placed in charge, known as "medical director of transportation." During the war it is said that as many as thirty well-fitted hospital steamers were used at different times in the East and West.

The best ocean transport of those times was the *J. K. Barnes.* She was a side-wheel steamer, 1,400 tons, 288 feet in length, 35 feet 2 inches in width, 22 feet 9 inches depth of hold. Her total capacity was 477 patients; she was used but ten months, during which time she carried 3,655 patients. Her plans may be seen in Figs. 1200–1202, of Vol. III. of the former edition of this Handbook.

During the recent South African war a hospital ship known as the *Maine* was fitted up by American women. This vessel is a duplicate of the *Missouri* and her equipment was similar. Her operating room was complete, and said to be the best in South Africa. She had accommodations for 218 patients, an *x*-ray machine, electric lights, fans, and diet kitchens, a completely equipped laundry, a steam disinfecting apparatus, refrigerating plant, etc. Her hospital force consisted of six medical officers, five women nurses, eleven male nurses, ten orderlies, and two apothecaries.

The *Trojan, Spartan,* and *Prince of Wales* were other ships fitted as hospital transports; the capacity of all four being about one thousand patients. These ships participated in the China campaign of the allied troops in 1900. During this campaign the Japanese, Germans, and French also had hospital transports, but the details of their equipment cannot be ascertained. It is said, however, that our own hospital ships, especially the *Relief,* were far superior to all others in equipment and facilities for caring for the disabled at sea.

Alfred E. Bradley.

HOT BORATE SPRING.—Lake County, California. This remarkable spring is situated near the town of Lakeport and on the edge of Clear Lake. The spring flows 18,000 gallons per hour, and has a temperature of 124° F. (July, 1888). On analysis it is found to contain the following mineral ingredients:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	86.82
Sodium bicarbonate	75.40
Sodium biborate	201.75
Potassium iodide	.12
Potassium chloride	Trace.
Potassium bromide	Trace.
Potassium bicarbonate	4.26
Ammonium bicarbonate	96.20
Magnesium bicarbonate	.73
Calcium sulphate	Trace.
Alumina	2.04
Silica	7.96
Organic matter	9.07
Total	484.35

Free carbonic acid gas, 30.75 grains.

An analysis by Dr. Moore shows a much smaller percentage of borax—103 grains per gallon. The spring is remarkable on account of the excessive amount of borax and ammonium salts which it contains. Professor Whitney states that the water is changeable both in its rate of flow and in its proportion of mineral ingredients. It is used in Lakeport and vicinity for kidney and bladder troubles. It is claimed that the water has dissolved a stone in the bladder.

James K. Crook.

HOT SPRINGS, BATH COUNTY, VIRGINIA.—

Post-Office.—Hot Springs. Hotels and cottages.

Access.—Viâ Hot Springs Branch of the Chesapeake and Ohio Railroad. Connection is made at Covington, Virginia. Through sleepers to Hot Springs are run in the summer. The Virginia Hot Springs Company run a line of first-class stages to the Warm Springs, five miles north, and to the Healing Springs, three miles south of the terminus at Hot Springs. The valley containing the Hot, Warm, Sulphur, and Healing springs of Virginia is located in the heart of the Appalachian Mountains, in the first of several lofty ranges that lie east of and parallel with the main Allegheny divide. Some two miles in width, the valley extends for more than a dozen miles between towering mountains, from the crests of which, 4,000 feet above the sea, villages and farm-houses with intervening stretches of country, over 1,500 feet below, are spread out to the view of the observer as a beautiful panorama. The visitor can drive for miles over new boulevards and carefully constructed roads. The streams formed by the various springs in the valley have pierced the western range and divided it into a series of five tall distinct mountains, narrowly separated from each other by chasms and gorges. Meandering roads and romantic bridle-paths and footways, bordered with ferns and mosses, penetrate these rugged and secluded passes. The altitude of the valley (2,300 feet) and its protection by the surrounding mountains from wind-storms and sudden changes combine to produce a temperature safe in winter and delightful all the rest of the year. The air is clear and dry, mists and fogs being rarely seen. The highest summer temperature observed during a series of recent observations was 87° F., the monthly mean for June, July, and August being 68.5° F.

The Hot Springs have been resorted to for three generations of white men. Physicians of wide reputation and abundant experience have pronounced them equal to the most effective similar waters of the European spas. The drinking-waters are also of great variety, and besides the hot springs there are magnesia, sulphur, soda, and alum springs, each of which is widely recommended for medicinal purposes. The bath-house at Hot Springs is a substantial four-story structure of stone and brick, built in the Colonial style of architecture at a cost of over $100,000. It is fitted up in a sumptuous manner with all the requisites of a modern institution of this kind. All varieties of baths will be found here. The old bath-house has been converted into two large swimming pools, one each for gentlemen and ladies. The hotels at Hot Springs are the "Homestead," a charming house of the true old Colonial style, which has been entirely remodelled and modernized, and the "Virginia," a new hotel built in the latest fashion, and supplied with every comfort and convenience. This hotel is kept open all the year. Ten new cottages cluster close by, each with a broad porch and veranda. This hotel is connected with the passenger station, but so arranged that no noise or annoyance is caused by railroad trains. The waters of the Hot Springs have been analyzed by several well-known chemists. The Spout, Boiler, and Sulphur Springs were examined by Professor Clarke, of the Smithsonian Institution in 1884, and the last two, together with the Soda and Magnesia springs, have recently been analyzed by Messrs. Dickoré and Morgan, of Cincinnati, Ohio. The several results in the examinations of the same waters have been practically identical. Following are specimen analyses:

Boiler (Bath) Spring.

(Analysis by Dickoré and Morgan.)

One United States Gallon Contains:

Solids.	Grains.
Magnesium sulphate	8.48
Magnesium carbonate	3.02
Calcium sulphate	1.89
Calcium carbonate	23.08
Sodium sulphate	3.68
Potassium sulphate	.69
Potassium chloride	.54
Silica	1.95
Total	43.33

Temperature, 108° F.

Soda (Drinking) Spring.

(Analysis by Dickoré and Morgan.)

One United States Gallon Contains:

Solids.	Grains.
Magnesium sulphate	5.90
Magnesium carbonate	2.61
Calcium sulphate	3.22
Calcium carbonate	17.55
Sodium sulphate	2.02
Potassium sulphate	.88
Potassium chloride	.21
Silica	.49
Total	32.88

Temperature, 74° F.

Spout Bath Spring.

(Analysis by Professor Clarke.)

One United States Gallon Contains:

Solids.	Grains.
Silica	1.37
Alumina	.15
Potassium chloride	.54
Potassium sulphate	1.09
Sodium sulphate	1.64
Calcium sulphate	8.32
Magnesium carbonate	7.02
Calcium carbonate	13.96
Total	34.09

Temperature, 106° F.

These waters resemble considerably in chemical composition those of the Hot Springs of Arkansas. They also resemble those of Aix-les-Bains in France, the French spring having a somewhat higher temperature. Both for internal use and for bathing the waters of the Virginia Hot Springs have gained a wide celebrity in the treatment of many of the ills to which human flesh is heir. The baths here are especially to be commended. The excellent thermal waters with the elegant and elaborate methods of using them may be expected to render all the service in diseased states which can be accomplished by this means. It is especially desired that all those who visit the springs with the intention of using the baths consult a resident physician in regard to the use of the waters.

The Healing Springs Hotel, three miles from the railway station at Hot Springs, is reached by a comfortable line of stages. It is connected by telephone with the depot and with the hotels at Hot and Warm Springs. No place in the Virginia Mountains is more pleasant or picturesque. The air is pure, dry and bracing, the temperature being uniform and delightful, throughout the season. The rooms in the hotel and cottages are large and cheerful; they are kept scrupulously clean, and the management throughout is charmingly homelike and in harmony with the surroundings. The supply of water is abundant, being derived from four springs of essentially the same character, and is beautifully bright and crystalline. Its temperature is uniformly 85° to 88° F. The bathing accommodations have been greatly extended and otherwise improved by the erection of a new bath-house, and by the addition of several apartments to those already built. The waters of these springs, as will be seen by the analyses, are almost identical with those of Schlangenbad and Ems in Germany. These were made by Prof. William E. Aiken, of the University of Maryland:

One United States Gallon Contains:

Solids.	Healing Springs.	
	Old Spring. Grains.	New Spring. Grains.
Calcium carbonate	17.90	18.72
Magnesium carbonate	1.24	1.96
Iron carbonate	.07	.28
Calcium sulphate	1.32	1.26
Magnesium sulphate	7.25	7.39
Potassium sulphate	2.21	2.53
Iron sulphate	.18	.10
Ammonium sulphate	.23	.23
Potassium chloride	....	.25
Potassium carbonate	.24	
Sodium chloride	.27	.29
Silicic acid	1.89	1.82
Organic acid (crenic ?)	.86	.88
Carbonic acid	2.20	2.29
Sulphureted hydrogen	Trace.	Trace.
Bromine	Trace.	Trace.
Sodium	Trace.	Trace.
Total	38.56	38.00

The bubbles of gas that rise from the springs contain in 100 parts: nitrogen gas, 97.25; carbonic acid gas, 2.75.

These waters have proved valuable in a considerable range of diseases; they are diuretic, somewhat laxative, and tonic in their effects upon the system. The best results have been observed in chronic congestion of the liver, in irritability of the bladder from cystitis, in enlarged prostate, etc., in the early stages of Bright's disease, and in debilitated states generally.

The *Warm Springs* are located five miles north of the railroad terminus at Hot Springs. The court-house and county buildings are located here. The springs are picturesquely located in a grand old grove and lawn in the centre of a tract of about 1,800 acres, which in width includes the crests of the mountains on either side of the valley. The remarks concerning the scenery, atmospheric conditions, etc., in the description of the Hot Springs apply with equal force to the Warm Springs. An excellent hotel, built in the Colonial style, charmingly situated and well-kept, will be found. There are also a number of comfortable cottages. For three generations the springs have been visited by people from all over the United States, with not a few from foreign countries, and even when it involved a long and tiresome journey in primitive stage coaches they were a favorite resort of the wealth and fashion of Virginia and the South. The grand boulevard recently completed between the Hot and Warm Springs is a magnificent driveway, and passengers will be transported from the Hot Springs station in comfortable carriages in the brief space of forty minutes after a most enjoyable ride. The gentlemen's bath is an octagon forty feet in diameter and holds 43,000 gallons of water. The ladies' bath is circular in shape, with a capacity of 60,000 gallons. These pools are supplied from separate springs discharging upward of 60,000 gallons of water per hour, at a temperature of 96° F., which, charged with myriads of bubbles of sulphureted hydrogen gas, rises naturally from the bottom of the pools, affording a delightful and luxurious bath. There are also private baths of various kinds, and ample provision for the comfort and convenience of bathers. An old analysis of one of the springs, made by Prof. A. A. Hayes, shows the following solid constituents:

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	5.22
Calcium sulphate	14.53
Potassium sulphate	1.38
Ammonium sulphate	.36
Sodium silicate Magnesium silicate	1.72
Iron crenate	2.50
Carbonic acid	6.92
Total	32.63

Gases: Sulphureted hydrogen, carbonic acid, and nitrogen.

The water is limpid, has a styptic taste, and the odor of sulphureted hydrogen. The action of the water is sedative, as a rule. Immersion in the bath gives rise to a sense of voluptuous repose and as the hand passes over the body the surface presents a velvet smoothness, as though anointed with some delicate ointment. This unctuous quality has also been observed in the baths of Molitz, in France, and in those of Wildbad near Stuttgart. It has been variously ascribed by European writers to the presence of silicates, to the monosulphuret of sodium, and to an organic matter, the last being the most probable cause. These waters, by reason of their soothing effects, are applicable in chronic and subacute rheumatism, gout, neuralgia, congestive amenorrhœa and dysmenorrhœa, and in nephritic and calcuious disorders. The spout bath, arranged with an ascending douche, is especially useful in the type of dysmenorrhœa named. The baths are also beneficial in the squamous skin affections. *James K. Crook.*

HOT SPRINGS, FALL RIVER COUNTY, SOUTH DAKOTA.—

Post-Office.—Hot Springs. Numerous hotels and cottages.

Access.—Viâ Fremont, Elkhorn, and Missouri Valley Railroad (branch of the Chicago and Northwestern system), or viâ the Chicago, Burlington and Quincy Railroad (Burlington route) direct to Hot Springs, arriving at the same depot by either route. This magnificent new spa is located in the heart of the Black Hills at an elevation of 3,400 feet above the sea level. The advantages of Hot Springs as a health resort are numerous. First as to the topographical features. The scenery in and adjacent to the place is varied and delightful. The lofty pine-clad hills, grand canyons, rippling streams, and beautiful falls of the Minnekahta and Cheyenne, make up a group of attractions difficult to excel.

Second as to climate. By reason of certain peculiar circumstances of location this resort is favored by very mild, equable atmospheric conditions. Summer days are followed by evenings of delicious coolness, while the autumns are unusually pleasant. During the winter months the temperature has maintained an average of 42° F. above zero for the last four years. Situated in the Minnekahta valley and sheltered on all sides by heavily timbered hills, cold winds and sudden changes of temperature are practically unknown. The winter temperature in the valley is from 20° to 25° higher than in localities only a dozen miles distant. It is said that the protection afforded by the hills is supplemented in no small degree by the millions of gallons of hot water flowing through the valley.

The visitor will find the accommodations prepared for his entertainment on a par with the charming scenery and genial climate. The largest hotel, the Evans, is constructed and equipped throughout in accordance with the latest and most approved methods. It is fully up to the standard of the best hostelries of the day. Other excellent hotels are the Gillespie, the Hot Springs, the Catholicon, the Davis, and the Parrott House. Cottages are also on hand for those who desire them. The hills afford attractive spots for camping out.

Adjoining the Evans House, and in full keeping with the elegant and elaborate appointments, is the Evans Sanitarium, containing sixty bath-rooms and embracing all varieties of baths. The Stewart Sanitarium, recently completed, also affords facilities for all kinds of bathing, including an excellent plunge bath. The Catholicon Sanitarium, now under construction, will add another to the attractive retreats of the Hot Springs. This structure, with the bath-house, will have a measurement of 100 × 75 feet, and will contain over 100 bath-rooms. The plunge bath is one of the prominent features of Hot Springs. It is constructed of stone, wood, iron, and glass and has 100 dressing-rooms. The building is 75 feet wide and 250 feet long, heated by steam and lighted by electricity. The water is at a natural temperature of 96° F. the year round. It increases in depth from three feet at one end to eight feet at the other. The springs at this resort are eight in number. The "Minnekahta" is the name given to a great Indian spring, the word being a synonym for health, pleasure, and recreation. It is said that the waters of this spring were in use by the Sioux and other tribes long before the approach of civilization. The natural temperature of this spring is 98° F. It furnishes the drinking fountain of the Evans House, the Evans bath-house, and the Minnekahta bathhouse. An analysis by Prof. Charles B. Gibson, of Chicago, resulted as follows:

One United States Gallon Contains:

Solids.	Grains.
Magnesium sulphate	4.32
Sodium sulphate Potassium sulphate	25.62
Iron peroxide	Trace.
Sodium chloride Potassium chloride	13.79
Calcium sulphate	16.32
Silica	2.46
Total	62.51

These waters are perfectly transparent, have a pronounced alkaline reaction, and contain no organic matter. Following are analyses of two of the other springs:

One United States Gallon Contains:

Solids.	Mammoth Mineral Spring. Grains.	Lakatah Spring. Grains.
Sodium sulphate	23.26	8.82
Potassium sulphate	5.63	3.33
Calcium sulphate	36.11	16.29
Calcium chloride	5.59	8.50
Ammonium chloride	.02	.05
Magnesium chloride	4.11	3.14
Calcium phosphate	....	.31
Magnesium nitrate	.30	.15
Magnesium phosphate	.10	
Magnesium carbonate	3.51	3.04
Iron sesquioxide	.15	.26
Alumina	.27	.02
Silica	1.55	1.83
Organic and volatile matter	12.11	8.05
Total	92.71	53.79

These waters are of the sulphated-saline and calcic variety. According to a report of the National Association of Railway Surgeons, which visited the resort several years since, "treatment by the Hot Springs water may be said to stimulate all the secretions and organic functions; to promote digestion and assimilation, and to favor tissue metamorphosis and excretion, thereby relieving internal congestions, stimulating blood-making, increasing the appetite, and favoring new and healthy tissues at the expense of the old and inactive." This treatment may, therefore, be confidently recommended in "gout and rheumatism after the inflammatory stage; in neuralgia, especially when depending upon gout; in metallic or malarial poisoning, paralysis not of organic origin, and neurasthenia; in the early stages of Bright's disease; in syphilis and functional diseases of the liver and stomach; in catarrhal affections of the respiratory tract . . ., and in chronic diseases especially of the squamous variety."

Hot Springs is the county seat of Fall River County, and is located about seventy miles south of Deadwood. The town has a permanent population of 3,000. Its proximity to extensive pine forests, in addition to the favorable features of location above mentioned, assists in preserving a mild and agreeable climate, and has brought the resort into much favor with persons afflicted with hay fever, asthma, and incipient phthisis.

James K. Crook.

HOT SPRINGS, GARLAND COUNTY, ARKANSAS.—

Post-Office.—Hot Springs. Hotels: Arlington, Eastman, Pullman, Avenue, Park, Bloomington, Josephine, etc. According to Cutler's Guide to the Hot Springs, there are as many as five hundred hotels and boarding-houses in the city.

ACCESS.—Viâ the Iron Mountain Route, the only line running to the Hot Springs. All lines leading into St. Louis connect in the Grand Union Depot with express trains of the Iron Mountain Route. From the south the best route is viâ Cairo, Columbus, Memphis, or Texarkana, connections being made at each of these points with Iron Mountain express trains. The springs are 55 miles southwest of Little Rock, the State capital, and 22 miles from Malvern, where trains on the Iron Mountain connect with the Hot Springs Railroad leading directly to the springs. Sleepers come through without change at Malvern. The Hot Springs are situated on the Mountain Creek and in the valley of the same name. They issue from the western slope of the Hot Springs Mountain, a spur of the Ozarks, at an elevation of from 700 to 800 feet above the Gulf of Mexico. The mountains on either side attain an altitude of 1,200 feet. The climate in this region, as a general rule, is mild and balmy and not subject to extremes of either heat or cold. Sunstroke is unknown, and the summer nights are generally cool and pleasant, light blankets, as a rule, being required before morning. The pure mountain air and constant southerly breezes unite in forming a healthful and invigorating climate. The lowest temperature observed in 1891 was 16° F., the highest 98° F., the average for that year being 84° F., or somewhat higher than the average for a series of preceding years. The rainfall for 1891 was 70.86 inches.

These springs have been known and utilized as a health resort since early in the century, and during that time they have acquired an extended reputation in the treatment of certain diseases. A city of considerable size and containing numerous excellent hotels, sanitariums, bathing-houses, and public buildings has been developed about them. Some of the handsomer and more commodious bath-houses were erected at a cost of from $10,000 to $50,000. Among the more prominent of these are the Eastman, Park, Alhambra, Superior, Palace, Magnesia, Ozark, Horseshoe, Rammelsburger, Lamar, and Maurice pavilions. The discharge of water from the springs amounts to 335 gallons per minute, or 482,000 gallons per day. These waters are nearly all concentrated in large, air-tight tanks, built by the United States Government, and are sufficient to bathe 19,296 persons daily, allowing twenty-five gallons for each bath. The springs are now seventy-two in number, another having recently been added to the list, according to a late annual report of the local board of health. From the United States Engineer's Report to the Hot Springs Commissioners we obtain the following table of temperatures of the springs:

Number.	Temp. (Fahr.)	Number.	Temp. (Fahr.)	Number.	Temp. (Fahr.)
1	77.0°	25	111.0°	49	131.0°
2	76	26	106	50	145
3	124	27	127.5	51	144
4	124	28	145	52	143
5	80	29	80	53	144.5
6	103	30	134.5	54	146
7	115	31	147	55	122
8	121.5	32	124	56	133
9	122	33	140	57	128
10	121.5	34	120	58	Sipage.
11	105	35	135	59	133
12	111	36	110	60	134.5
13	135.5	37	120	61	135
14	137	38	128	62	109
15	134	39	125.5	63	83
16	131	40	112	64	135
17	Sipage.	41	157	65	141
18	93	42	Sipage.	66	87
19	84	43	144	67	Sipage.
20	83	44	Sipage.	68	131
21	106	45	111	69	83
22	122	46	Sipage.	70	89
23	125	47	144.5	71	94
24	113	48	91		

Highest temperature, 157° F.; lowest, 76° F.

Those marked "sipage" are intermittent. All others are constant and unvarying in heat and quantity. All the springs on the east side of Hot Springs Creek flowing from Hot Springs Mountain, except one under the Rammelsburger bath-house, are hot. All on the west side, except the Alum spring, are cold. No complete analysis of the waters seems to have been made since the now some what antiquated one made by Prof. E. Hills Larkin, in 1859. It is as follows:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Magnesium carbonate	0.13
Calcium carbonate	3.97
Sodium sulphate	.38
Potassium sulphate	.23
Calcium sulphate	.11
Sodium chloride	.01
Calcium silicate	.46
Sodium	Trace.
Bromium	Trace.
Iron sesquioxide	.10
Alumina	.45
Silica	1.87
Organic matter	.70
Water (?)	.14
Total	8.55

The water also contains a considerable quantity of free carbonic acid. Persons taking the baths here should always do so under the supervision of one of the local physicians. Those affected with organic disease of the heart or recognizable physical signs of consumption are not allowed to bathe, as the thermal action of the water is liable to be prejudicial to such cases. If the lungs are but slightly involved, careful bathing may be permitted. Furthermore, cases of simple cardiac palpitation are not excluded. As each case must be treated on its merits, and as detailed instructions are given by the local physician, it is unnecessary here to enter into a minute description of the bathing process at Hot Springs. Suffice it to say that patients are usually (not invariably) required to bathe six minutes in water at 96° to 100° F., two to six minutes in the vapor bath-rooms, and five to twenty minutes in blankets according to the time required to induce perspiration. The course here has been found especially beneficial in diseases of the genito-urinary system, especially syphilis, and in gout, rheumatism, and neuralgia. The baths are also recommended on high authority in various skin affections including eczema, psoriasis, urticaria, impetigo, prurigo, rupia, etc.

The city of Hot Springs itself is well drained and well lighted, and has ample police and fire protection. It now claims a population, resident and visiting, of 21,000. About 50,000 persons visit the place annually, and this number is ever on the increase. The United States Government Army and Navy Hospital, recently erected, cost $200,000. It is said that the Arlington Hotel, with its bath-house attached, will have cost over $500,000 when completed. Among other mineral springs within the limits of the city of Hot Springs, or in the neighborhood, are the following: Allen's Alterative Spring, situated on Central Avenue, in the heart of the city; Gillen's White Sulphur Springs, located three miles from Hot Springs; Mountain Valley Springs, situated twelve miles north of Hot Springs, at the foot of Blakely Mountain, in a beautiful Valley extending well up into the mountain range; and Potash Sulphur Springs, located seven miles east of Hot Springs on the Hot Springs Railroad, one mile from Lawrence station. *James K. Crook.*

HOT SPRINGS, MADISON COUNTY, NORTH CAROLINA.—

POST-OFFICE.—Hot Springs. Mountain Park Hotel and boarding-houses.

ACCESS.—From the north and east by through Pullman cars on the Pennsylvania and Southern Railroads; from the west and northwest viâ Louisville, or viâ Cincinnati by the Queen and Crescent route to Knoxville, thence by East Tennessee, Virginia and Georgia Railroad (now a part of the Southern system). The location is 35 miles west of Asheville. The picturesque little village of Hot Springs is situated on the western boundary of North Carolina, only three miles from the Tennessee line, in the heart of Big Smoky and Blue Ridge Mountains, on the banks of the beautiful French Broad River. The location is 1,700 or 1,800 feet above the sea level. The atmosphere is dry and invigorating and the climate mild and equable, there being a very large proportion of clear days. The springs have long been popular in the South, but in recent years they have come into high favor with Northern visitors also. They are about twenty in number, and the temperature of the waters ranges from 96° to 104° F. They form one of the only two groups of hot springs east of the Mississippi from Canada to the Gulf of Mexico. The following analysis was recently made by Professors Chandler and Pellew, of New York:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	1.08
Potassium chloride	.62
Potassium sulphate	1.62
Calcium sulphate	20.04
Magnesium sulphate	7.20
Ammonium bicarbonate	Traces.
Calcium bicarbonate	9.02
Iron bicarbonate	.10
Sodium phosphate	Traces.
Alumina	.04
Silica	3.14
Organic and volatile matter	Traces.
Total	42.86

The waters are quite similar to those of the Arkansas Hot Springs. Several of the springs have been encompassed in the limits of a fine, large bath-house, which is divided into sixteen separate pools, nine feet long by six feet wide and four to five feet in depth. The water pours into these pools directly from the springs. The visitor will find here all of the modern appliances and improvements which go to make up a first-class bathing establishment of the day. Guests are received at all times of the year. With its lovely mountain scenery, its exhilarating climate, its thermal waters, and many other natural attractions, combined with a hospitable and scientific management, this resort is well deserving of the wide reputation which it has obtained. *James K. Crook.*

HOT SULPHUR SPRINGS.—Middle Park, Grand County, Colorado.

POST-OFFICE.—Hot Sulphur Springs. Hotels.

ACCESS.—Viâ Union Pacific Railroad, 50 miles west from Denver to Georgetown; thence by daily stage 50 miles to springs, passing over the Snowy, or main range, of the Rocky Mountains, at 11,250 feet altitude.

These springs are located in the Middle Park on the banks of the Grand River, 7,625 feet above the sea level. This river forms the only drainage outlet to the Middle Park, a mountain basin 90 by 50 miles in extent. The enclosing peaks vary in height from 9,000 to 14,000 feet.

The prevailing weather in this section is clear, with westerly winds. There is considerable snow in winter, with a steady range of temperature of about 32° to 50° F., but occasionally dropping to 20° or 25° below zero. As many as twenty-two of the springs are well situated for improvement, but, according to the latest reports we have had, the baths now in use take water from only three or four. The exact flow of water cannot be stated, but it is believed to be greater than that of the Arkansas Hot Springs. A strong smell of sulphureted hydrogen pervades the neighborhood of the springs, and with a favoring wind may be noticed for a considerable distance up the valley. The channels through which the waters flow are lined with a soft yellowish-white, velvety substance having the odor of sulphur (probably a confervoid growth known as sulfuraria). This substance is evidently not a sediment, as it stands up like the pile of velvet or plush, and is not deposited in layers, while the water itself is as clear and bright as that of any mountain spring. It is said to be very palatable and to rest well on delicate stomachs. The following analyses were made some years ago by Professor Mallett, Jr.:

ONE UNITED STATES GALLON CONTAINS:

Solids.	No. 1—Red sulphur, temp. 109.5° F. Grains.	No. 2—Saline, temp. 91° F. Grains.	No. 3—Alum, temp. 97.5° F. Grains.	No. 4—Little sulphur, temp. 111° F. Grains.	No. 5—Big sulphur, temp. 80.56° F. Grains.	No. 6—Bath spring, temp. 117° F. Grains.
Calcium carbonate	10.08	......	......	8.46	3.68	6.43
Sodium carbonate	58.57	50.45	20.37	29.42	39.37	22.42
Magnesium sulphate	......	......	5.26			
Magnesium carbonate	6.57	4.14	......	2.66	1.93	
Sodium chloride	14.61	......	13.29	12.18	13.97	13.11
Sodium sulphate	8.48	8.97	17.53	14.25	9.85	25.11
Sodium silicate	......	1.46				
Potassium sulphate	.50	.07	1.03	7.03	.96	1.69
Free carbonic acid	2.94	......	8.42	.42	9.49	4.69
Silicic acid	......	......	.61	.54	1.31	1.36
Lithia	Trace	Trace	Trace			
Iron	Trace	Trace	Trace	Trace	Trace	Trace
Ammonia	......	Trace	Trace	Trace	Trace	Trace
Total	101.75	65.09	66.51	74.96	80.56	74.81

The supply of water furnished for this analysis was insufficient to detect solids present in minute quantities. The lithia was discovered by means of a spectroscope in the residue left after evaporating 300 c.c. of the water. No gaseous constituents are shown, as the analyses were made from bottled water, which had been standing for some time after removal from the springs, and it is believed that the sulphureted hydrogen (or other gas) which may have been present had either escaped or been oxidized to sulphuric acid.

The waters are recommended in cutaneous, hepatic, uterine, neuralgic, gouty, and rheumatic disorders, and for the manifestations of tertiary syphilis. As with thermal waters generally, they are contraindicated in most acute diseases, in tuberculosis and cancer, in fatty degeneration of any important structure, in aneurism or organic heart disease, and in predispositions to cerebral, gastric, pulmonary, or intestinal hemorrhage. There are two hotels at the Hot Sulphur Springs and several private houses where guests may obtain accommodations.

James K. Crook.

HOUSE SANITATION.—The primary objects of habitations is to secure protection from the influence of heat and cold, rain, sunshine, and storms, and thus promote the health and happiness, and indirectly also, the morals and culture of the human race. The influence of sanitary houses cannot be overestimated. Dr. Villermé, in an investigation in France from 1821 to 1827, found that of the inhabitants of arrondissements containing 7 per cent. of badly constructed dwellings, 1 person out of every 72 died; of inhabitants of arrondissements containing 22 per cent. of badly constructed dwellings 1 out of 65 died; while of the inhabitants of arrondissements containing 38 per cent. of badly constructed dwellings 1 out of every 45 died. The history of improved dwellings for wage-earners shows everywhere a lessened death rate.

1. *Site.*—One of the first requirements of a sanitary home is a salubrious building site with a thorough exposure to air and sunlight; the top of a small elevation is always to be preferred, because of better natural drainage, purer air, freedom from dampness, and greater safety from inundations. Hippocrates and Vitruvius have referred in their writings to elevation as a desirable factor. The tops of the highest hills are usually too much exposed to the wind, and when chosen in certain climates the house should be protected by trees on the windward side; next to the top of a hill, the slopes should be preferred with a southern, southeastern, or southwestern exposure, on account of the advantages of sunlight and greater cheerfulness. Sites located in depressions which receive the natural drainage from surrounding slopes should be avoided, as they are not only damp, but likely to be surrounded with cold air and chilling mists. It is scarcely necessary to insist that so-called "made soil" and close proximity to marshes and injurious industrial establishments should be avoided.

Next to the topography of the site the character of the soil is important in its influence upon the healthfulness of the home. In a general way a gravelly, sandy, or chalky soil of good depth on a slope makes the best building site, provided soil pollution has not taken place and the deposit is not upheld by some impermeable stratum of clay or rock near the surface. Clay, marl, peat, and made soils should be avoided, because they are damp and the presence of organic matter, apart from favoring the proliferation of disease germs, also tends to pollute the ground air which is in constant communication and interchangeable with the atmosphere. (See Dr. Charles Smart's article on *Air*, p. 159, Vol. I.)

While rock affords easy facility for surface drainage, Mr. T. M. Clark (REFERENCE HANDBOOK OF THE MEDICAL SCIENCES, first edition, Vol. III., p. 423) regards it as very objectionable, as the ledges are full of seams through which water usually flows, and the trenching necessary for the interception of the springs formed in this way is so costly that it is usually neglected, and cellars built on rock are in consequence generally damp.

The temperature of the upper layers of soil, and hence also its dryness, depend largely upon its exposure to the sun; but it is well known that heat is variably absorbed and retained in different soils equally shielded or unshielded by vegetation. The following table by Schubler shows the capacity of different soils of absorbing and retaining heat—100 being assumed as the standard:

Land with some lime..	100.0	Clayey earth	68.4
Pure sand	95.6	Pure clay	66.7
Light clay	76.9	Fine chalk................	61.8
Gypsum	72.2	Humus.......	49.0
Heavy clay............	71.1		

It will be seen, therefore, that sandy soils are warmer and clayey soils are not only damp but also very much colder.

Unfortunately, "ideal building sites" are within the reach only of comparatively few, and steps must therefore be taken to render objectionable sites as sanitary as possible; for the purpose of securing dryness, attention must be paid to the prompt removal of surface water and of subsoil water, the site should be drained by means of suitable drains four to six feet below the floor of the cellar or basement; indeed this precaution should not be neglected even in comparatively dry soils in order to limit the fluctuations of the ground water. In the preparation of the building site it is always desirable to excavate sufficiently deep to get rid of surface pollution, and it is perhaps needless to insist that in grading no soil containing the rubbish and wastes of human life and occupation should be used. In isolated buildings the surface drainage should be directed away from the house and the environments improved, with due regard to light and air, by either favoring the growth of vegetation or by removal and pruning of excess and overproduction.

2. *Building Material.*—The most common materials used in the construction of buildings are wood, brick, sandstone, limestone, granite, marble, iron, steel and other metals, glass, cement, mortar, asphaltum, and concrete. Of these materials, iron, zinc, copper, cement, slate, vitrified brick, and granite are quite impermeable; while others are not; depending upon the degree of their porosity and hygroscopic properties—according to Lang—

	Per cent. of water by volume.	Or, per cent. by weight.
Soft-burned bricks absorb	32.70	19.13
Hard-burned bricks absorb	28.20	16.50
Mortar burned bricks absorb.................	26.00	14.80
Portland cement absorbs.....................	17.80	11.00
Limestone absorbs...........................	17.70	7.26
Dolomite absorbs	14.70	6.50
Sandstone absorbs	10.80	4.34
Porphyry absorbs	2.75	1.05
Slate absorbs...............................	.93	.35
Granite absorbs.............................	.61	.23
Marble absorbs	.59	.32
Serpentine rock absorbs	.56	.22
Vitrified bricks absorb	.00	.00

A wall built of ordinary brick and mortar is capable of absorbing large quantities of water. Pettenkofer has calculated that 10,000 gallons are incorporated in a house built of 100,000 ordinary sized bricks. Bricks burned from clay containing much saltpetre and sulphate of sodium are especially objectionable, as a deposit is formed on the outside of the walls and moisture is attracted.

Galton, in his work on healthy dwellings, has shown that marble and limestone conduct more heat than an equal thickness of glass, bricks, plastering, and wainscoting. This appears to prove what experience has practically demonstrated, that frame and brick buildings are more readily warmed than marble and limestone structures of equal size and thickness of walls.

The hygienic importance of the properties of the building material cannot be underrated. Its porosity largely determines the interchange of air through the walls and the temperature of the rooms, thus greatly influencing ventilation and heating. The pores, as in the soil, contain either air or moisture; if air, the heat is conducted slowly, whilst water conducts heat readily. The hygroscopic properties of the material influence capillary attraction and diffusion of moisture, and consequently also the permeability and heat-conducting powers of the walls. Walls saturated with moisture absorb much heat and render transpiration of air impossible. It is for this reason that a house with damp walls appears much cooler to the inmates in summer than a dry one; but damp walls are decidedly objectionable, because they not only render the air of the room damp and impure and abstract more heat from the inmates, but also favor the growth of micro-organisms.

It will be readily understood that the application of paint, wall paper, and even calcimining will affect, if not completely check, the transpiration of air through the walls. For hot climates, frame and other forms of wooden buildings possess the advantage that they cool off very rapidly after the sun has disappeared, but because of their inflammability, short duration of life, and other sanitary disadvantages, such buildings cannot be recommended. But, as long as they are being extensively used in this country, special precaution should be taken in planning such buildings to prevent the entrance of cold winds at the junction of the wood walls and the stone underpinning. For this purpose Mr. Clark recommends a few courses of brick in mortar to be laid upon the cellar wall just behind the wooden sill; and as regards the exclusion of cold air through cracks or crevices in the cornice, he suggests the construction of a four-inch wall of brick and mortar on top of the plate which forms the top of the wall and supports the floor of the rafters, carrying it up until it meets the roof boarding. This wall, besides its use in keeping out cold winds, is also of some value in checking the spread of fire. Frame houses can be rendered cooler in summer and warmer in winter by double plastering inside and by covering the outside walls first with rough boards and a layer of Cabot's quilt and an exterior finish of clap-boards or shingles.

In spite of certain objections to brick, they are on the whole the most desirable material for ordinary dwellings; they resist fire better than any other material, and a hard-stock pressed brick of a light color is quite impermeable to moisture and makes a pleasing and hygienic outer wall. Next to brick, granite, marble, lime and sandstone are most frequently used, especially in connection with iron and steel in the construction of fireproof buildings. None of these rocks can resist the ravages of fire as well as brick; granite is better than marble, lime, or sandstone in this regard.

Micro-organisms in building material are especially numerous in the filler for ceiling spaces, which is frequently selected without regard to its source, old plaster and other rubbish being used; Emmerich has isolated the pneumococcus in such material, and Bonome found the bacillus of tetanus in mortar.

The latter being a mixture of sand and lime, the inference is that it was derived from sand, and that the spores were not destroyed by the action of the lime. Wall papers, unless very smooth, harbor a large number of microorganisms; we also know the danger of house fungi, especially the "merculius lacrymans," in bringing about the "dry rot" in pine lumber, as well as the frequent occurrence of moulds in dark and damp places.

Construction of the House.—Dryness of the foundation and walls, as already indicated, must be secured by draining the subsoil four to six feet below the cellar or basement and covering the entire floor with a layer of cement concrete six inches thick, rammed solid, and this should be coated with one inch of cement. In this way not only dampness, but the equally obnoxious ground air are excluded. To prevent the dampness of the soil from rising in the walls by capillary attraction, the foundations must be laid in concrete and hydraulic cement and a horizontal course of slate bedded in cement should be interposed between the concrete footings and wall, and another course of slate just as the foundation walls reach the ground level. Since these slate courses are liable to fracture, the last damp-proof course should consist of vitrified hollow brick, which, moreover, possess the advantage of securing ventilation. Some architects recommend damp-proof courses of tarred-felt asphalt or sheet lead (Figs. 2711 and 2712).

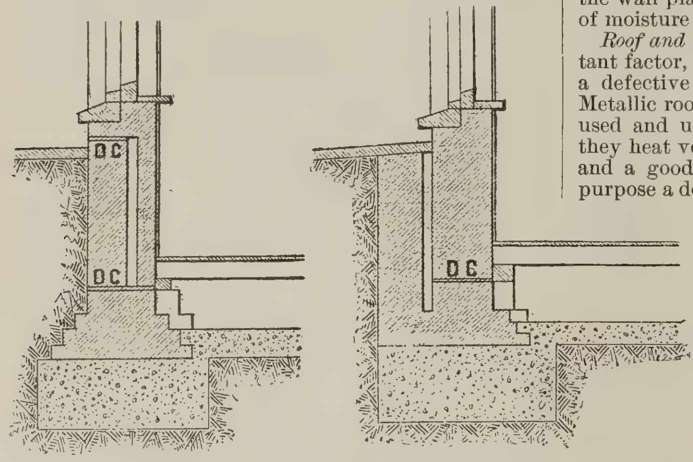

FIG.. 2711. FIG. 2712.

FIGS. 2711 and 2712.—Methods of Preventing Dampness of Walls. Letters *D C* denote location of damp-proof course. (Munson.)

The exterior walls of a house, whenever practicable, should be separated from the ground by an "open area," extending from the foundation upward; but where this cannot be done, a "dry area" may be formed by constructing a hollow wall to the ground level, provided with the usual damp-proof courses, and if springy, also with a subsoil drain at the bottom, at the same time protecting the wall in contact with the ground with a coat of slate embedded in cement. Mr. Clark suggests that if the ground is springy, a strip of tarred roofing felt, a little wider than the wall, should be laid upon the footings just below the cellar floor, and the stonework continued upon it. This, he says, "will prevent moisture from rising in the walls by capillary attraction from below, and with the coal-tar coat on the outside, a cellar with walls of porous material may be made dry and wholesome at small expense," but we cannot vouch for the durability of this procedure.

In localities with considerable rainfall it will be well to protect the side or rear walls of a rough brick building from driving rains with either a coat of cement, mineral paint, tar, or glazed tiles. Such a precaution is unnecessary when hard-pressed bricks are used. Reference has already been made to the fact that during the construction of a building an immense amount of water is incorporated with the bricks, mortar, and plaster. This water should be gotten rid of before the house is occupied, by thorough airing and drying; but not too rapidly, as a rapid evaporation prevents the carbonate of lime from becoming crystallized and the mortar loses its binding qualities. If the house has not been properly dried, the walls are very likely to sweat, which is in part due to their own moisture and partly to the condensation of the respiratory vapors on the damp cold walls. Laveran states, that a building is not fit for occupancy as long as the wall plaster contains more than twenty-two per cent. of moisture (see Examination, p. 768).

Roof and Roofing.—A good dry roof is another important factor, because water often gets to the walls through a defective roof and the whole house becomes damp. Metallic roofs with a sufficient pitch are most commonly used and usually secure this needed protection; but as they heat very rapidly a tin roof should be painted white and a good non-conductor should intervene. For this purpose a double course of boards with a layer of Cabot's quilt, corked or Florian building-paper may be used. The tin, of course, is properly secured to the upper sheating with a layer of felt paper directly beneath the tin. In any event there should also be an air space of two to three feet between the upper ceiling and the roof, and this space should be ventilated with perforated bricks in the walls and circular ventilators at the highest points of the roof. It is also a good plan, in order to prevent rusting, to cover the tin with a coat of mineral paint on the under side. Slate, cement, and tiled roofs, when properly constructed, afford protection against dampness, fire, and heat. In rural districts wooden shingles are still extensively used, and such roofs when treated with creosote and covered with rubber or metallic paint last for about twenty years. Whatever kind of a roof is used, free access to it should be provided by means of stairs or a ladder through a suitable opening, which in summer can be utilized for the escape of hot air. Special attention should be paid to the gutters and rain leaders; the openings of the latter should be protected with a network of galvanized iron, so as to prevent dead leaves, scraps of paper, mortar, birds' nests, etc., from passing through and clogging the conductors. The gutters should be periodically cleaned to prevent accumulation of rubbish and the overflow resulting therefrom. Subsequent leaks and defects should be promptly repaired. A leaky rain spout may keep the entire house damp. Copper or galvanized iron should be chosen instead of tin for gutters and conductors.

Floors.—Hygiene demands that the floors should be impervious to dirt, moisture, and germs, and should therefore be well seasoned, tongued, and grooved, closely matched and laid in white lead. All crevices resulting from subsequent shrinkage should be neatly filled with strips of wood, putty, paint, or wax. There should be a sub-floor of rough pine with a double layer of Florian building paper between; the top floor should not be laid until after the building is trimmed out; it should then be planed off and treated with a mixture prepared as follows: Dissolve by heat one pint of paraffin pared into shavings in two pints of raw linseed oil. To this solution add two pints of liquid dryer and sufficient turpentine to thin it to the desired consistency. This will give a gloss finish. If a dead finish be desired, about one-half of the quantity of paraffin should be used; apply with brush the same as varnish. If a high degree of polish be desired, rub with a polishing brush. One gallon of this mixture will cover approximately two hundred square feet of floor surface.

Oak and other hard-wood parquetry floors are not only attractive but also offer every hygienic advantage. In warm climates cement or "granito" floors may be advantageously used. The latter are really nothing more than a concrete-cement floor, four to six inches in thickness, with chips of marble and granite of various colors embedded in the upper layer and polished. They are practically insect and vermin proof, especially desirable for kitchens, pantries, and bathrooms, and should supersede the use of linoleum and rubber floor coverings. As a filler for the ceiling space, with a view of deadening sounds and as a protection in case of fire, special hollow bricks, dry cinders, clean dry mortar and peat, impregnated with milk of lime, have been used. Metallic laths are preferable to wood.

Stairs.—The stairway should be so constructed as to afford an easy ascent with risers not exceeding seven inches in height and treads from ten to twelve inches in width. For public buildings and tenement houses iron stairs and fire-escapes are demanded; indeed, even private houses would be better off with these safeguards in case of fire.

Halls.—The halls of a house should be roomy, well-lighted by direct light, if possible, and susceptible of ventilation. In a modern private dwelling the hall on the first floor is five to six feet in width and leads into the reception room, from which proceeds an open stairway to the upper floors. The open stairway should be lighted and ventilated by means of a skylight.

Interior Arrangements.—In regard to the size of the dwellings it is always best if they are simply large enough to accommodate one family. Overcrowding should be avoided, as infectious diseases are more liable to spread in consequence of aerial infection and the more intimate contact of the occupants. Körösi, of Budapest, has shown that out of every one hundred deaths from contagious diseases, there were:

20 deaths in dwellings with 1 to 2 persons in each room.
29 " " " " 3 " 5 " " " "
32 " " " " 6 " 10 " " " "
79 " " " " over 10 " " " "

The following table, prepared by Rohé, shows the relation of death rate to density of population:

City.	Mean number of inhabitants to each house.	Average annual death rate per 1,000 inhabitants.
London	8	24
Berlin	32	25
Paris	35	28
St. Petersburg	52	41
Vienna	55	47

It would be unfair, however, to attribute this increased death rate solely to overcrowding; other factors must be considered, since, as well expressed by Ogle, "The more crowded a community the greater, generally speaking, is the amount of abject want, of filth, of crime, of drunkenness, and of other excesses." Nevertheless, these mortality statistics demonstrate the baneful effects of tenement houses. With the present rapid-transit facilities in every city, our voice should be clearly in favor of individual homes; and when this is impracticable, we should insist on broad streets and deep yards. No more than sixty-six per cent. of the lot should be covered by the house, and the height of the building should never exceed the width of the street. No field affords better opportunity for philanthropic work than the removal of slums and erection of sanitary houses for wage-earners at reasonable rentals. Acting upon this, the Washington Sanitary Improvement Company was organized in 1897, and Surgeon-General Sternberg prepared plans in which no detail was omitted which would tend to provide the best accommodations from the standpoint of hygiene. Each house has a frontage of 17½ feet and consists of two independent flats, one on each floor, the special feature being that each flat constitutes a complete home, having a separate entrance and exit, separate yard and cellar. The entrance to the flat on the first floor opens into the front or sitting-room, 13.2 by 14 feet; back of this room is a hallway leading to the bedrooms, 12 by 13.2 feet, bathroom 5.6 by 5.6, and kitchen 10 by 12.4 feet. The entrance to the flat in the second story is by a staircase with access through a doorway on a level with the one opening into the flat on the first floor, but at the other end of the front of the house. Each flat has three large closets, and the kitchens are provided with a range, hot-water boiler, dressers, and sinks. Every room receives direct light and air, and the plumbing is the best. These flats rent for $12 per month, with a rebate of one month's rent every year to tenants whose apartments have not required repairs. The company has paid five-per-cent. dividends from the beginning and accumulated a surplus fund at the rate of two per cent. per annum. No officer receives any compensation, and this promotes the philanthropic aspect of the enterprise by providing the very best accommodation from the standpoint of hygiene, and as to comfort the utmost which a given cost will provide. The company was awarded a gold medal at the Paris Exposition in 1900, the only company in the United States to receive that award.

Basements are always desirable, even in small houses, for store-rooms, heating plants, and kitchens; they should be at least eight feet from floor to ceiling, not over one-half below ground, well lighted, and with all precautions taken to prevent the odors of the kitchen from passing into the upper stories. This can be done by a closed stairway and a deep hood over the range, which should conduct the gases into a flue located next to the smoke flue. In the more commodious houses the first floor usually consists of three large rooms, parlor, reception, and dining-room, to which in double houses a library may be added. When practicable, the kitchen should be located in a one-story wing with pantry intervening between the kitchen and dining-room. This isolates the kitchen and odors from the main house, and is preferable in many respects.

The rooms of the first floor, or parlor floor, should be from 10½ to 11 feet high and liberally supplied with windows, while the upper stories may be 10 and 9½ feet in height. Living and sleeping apartments for obvious reasons should not be tolerated in basements. The largest and sunniest apartment in the house should be chosen for the nursery and living room. The bedrooms should also be bright and sunny, and rooms with northern exposure avoided as much as possible for regular bedrooms. In this connection the stimulating effects of sunlight upon tissue metamorphosis and its destructive influence on micro-organisms should be remembered. No room should have a borrowed light, and this can be avoided by the construction of ample air and light wells in city houses which are three or four rooms deep. The windows should be made to open on top and bottom.

Interior Finish and Decorations.—Hygiene cannot approve of decorations or an interior finish which serve as dust and germ traps. In all houses dust is produced by the wear and tear of domestic activities, and our object should be to prevent its accumulation and facilitate its removal. Cornices and projections on ceilings and walls, the mouldings of door and window frames, wardrobes, carpet and cumbersome draperies all tend to collect dust and micro-organisms; they are not tolerated in hospitals and should be abolished in sanitary houses.

When the floors are neatly polished, it is quite sufficient to have a few small rugs which can be easily taken up and shaken and the floors cleaned with a damp duster. Heavy curtains and draperies should give way to light, airy fabrics, which can be easily washed. The bedroom furniture should be light, simple, and limited to the most necessary articles. Every bedroom should be provided with a commodious closet, supplied with clothes hooks, shelves, and drawers, and if the mirror is sunk in the panel of the door, wardrobes and dressing-cases could be conveniently dispensed with. All corners and angles of the inside of the house should be rounded to facilitate the removal of dust.

Wall Decorations.—The wall coverings should be as smooth as possible, since rough and highly-embossed paper and hangings accumulate an enormous quantity of dust and germs. On the whole, the plain calcimined or painted walls outrank from a sanitary point of view the gorgeous decorations of the palatial homes. Green paint and green-colored wall papers should be rejected; indeed, since arsenic has been found in various colored papers other than green, no paper should be used unless guaranteed to be free from arsenic, as much harm may be done by arseniuretted hydrogen, which tends to produce a chronic form of arsenical poisoning, characterized by conjunctivitis, cough, nausea, and diarrhœa, with colic, cramps, and debility.

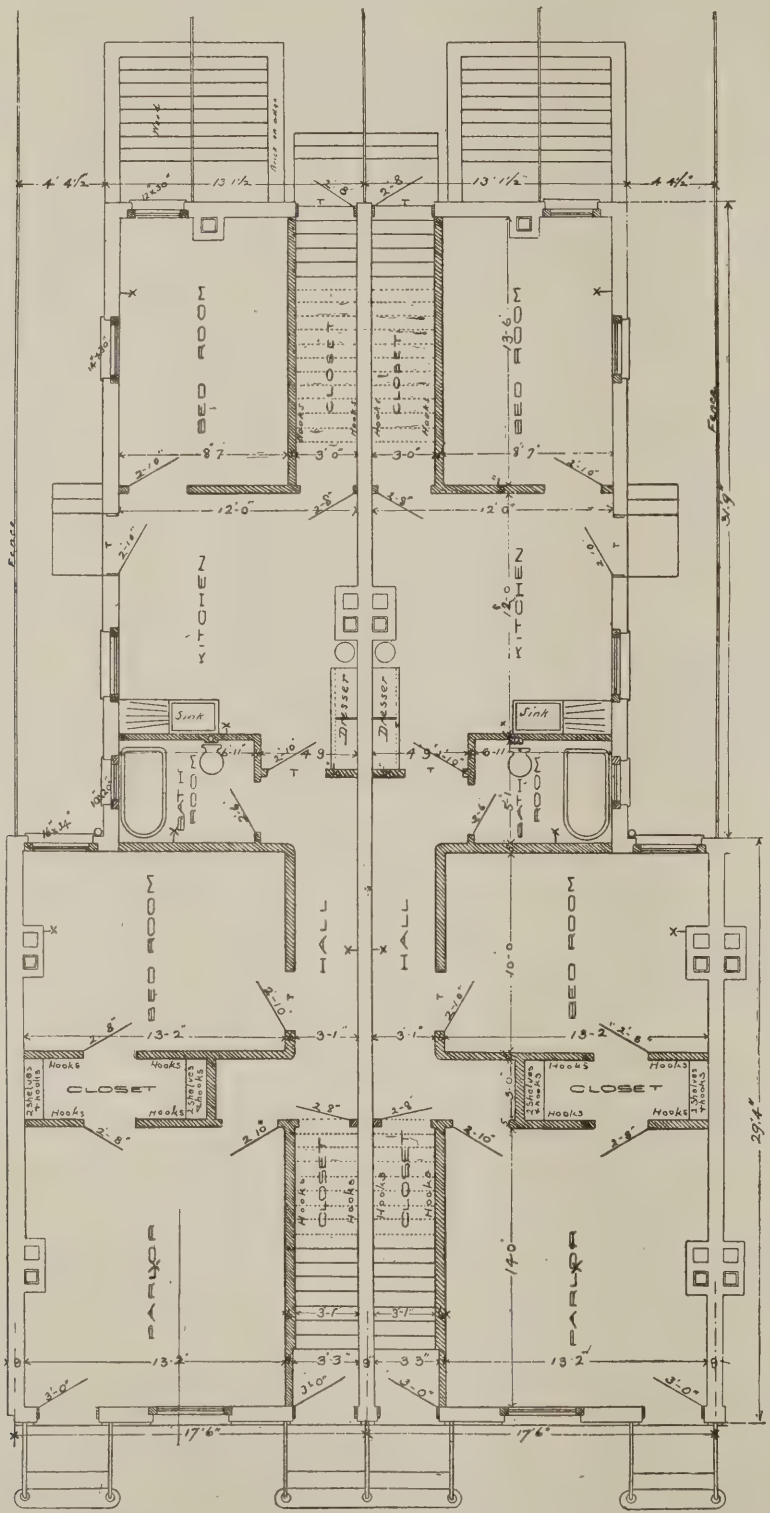

FIG. 2713.—First-Story Plan of Sanitary Houses for Wage-earners in the City of Washington.

The air of habitations differs from the exterior air in this, that unless precautions have been taken it may contain the elements of ground and sewer air; but even in the best-appointed houses the air is vitiated by the products of respiration, combustion, and decomposition of organic matter. As a matter of fact we always find an excess of carbonic acid, as much as 5.88 volumes per 10,000 having been determined in basements, 4.59 on the first floor, 4.50 on the second floor, and 4.19 on the third floor. We also find an excess of organic matter, most probably derived from the lungs, mouth, and skin of the occupants. Some authors deny that the skin and lungs in perfect health give off anything impure, but experience points to the fact that even the cleanest and healthiest persons exhale an organic substance which clings to bedding, clothing, carpets, and walls, and imparts that peculiar close and offensive odor to bedrooms and other inhabited apartments. Indeed, Uffelmann never failed to find ammonia nitrates in the air of his rooms, amounting to from 0.108 to 0.072 mgm. as compared with 0.025 mgm. per cubic metre in the outer air.

We also find more dust and germs than in the open air. If on a wind-still day we expose two glass slides moistened with glycerin, one in the outer air and the other indoors, we shall find at the expiration of twelve hours that the slide exposed indoors will contain a larger amount of dust, and that the organic constituents which in the outer air amount to about thirty per cent. are present to the extent of about fifty-seven per cent. It has also been shown that when the exterior air contained only 6.5 mgm. of dust per cubic metre, the air of even well-ventilated houses contains an average of 16.8 mgm. per cubic metre.

The number of micro-organisms in the air of even the better class of houses is invariably greater than in the open air, and depends largely upon whether the dust has been stirred up or not. Thus Uffelmann found the outer air thirty-nine inches above ground to contain 250 germs per cubic metre; one of his rooms during a perfect calm to contain 7,500 per cubic metre, and one, after shutting two of the doors vehemently, 27,000 per cubic metre.

Cellar air contains usually more organic matter and CO_2, and the degree of humidity amounts often to complete saturation; but the number of germs is less than in other parts of the house.

The *relative humidity* of the air of habitations when not heated is usually quite constant. It is, of course, influenced by the exterior air, but the fluctuations are never so marked as outdoors. This is probably due to the fact that the walls and furniture absorb moisture and give it off to less hygroscopic substances.

The *temperature* of habitations, with the exception of the upper floor, is also very much more constant than that of the open air. The maximum temperature in summer usually occurs five hours later than in the open air; for this reason our houses are hotter about six o'clock in the evening than at twelve or one o'clock. The thickness and construction of the walls determine this to a great extent. Houses constructed with walls having a four-inch air space are cooler in summer and warmer in winter.

Ventilation.—When we consider that an adult individual exhales on an average 14.4 cubic feet of CO_2 during twenty-four hours, and recall the other polluting factors, such as the products of combustion and decomposition, and that the presence of individuals tends to vitiate the air with dust, germs, and organic matter from the skin, mouth, and lungs, while the watery vapor eliminated by the lungs and skin, amounting to about 550 grains per hour, is sufficient to saturate 90 cubic feet of air at a temperature of 60° F., we see at once the necessity for the renewal of air in our habitations. Since it would be neither prudent nor expedient to wait until the air becomes literally unfit to breathe, it is self-evident that the dilution of impure and diffusion of pure air should be constant and gradual. The next question arises, How much fresh air is required to renovate the vitiated air? It has been found by careful observation and experiments that no appreciable organic odors are perceived in the air of inhabited rooms until the volume of CO_2 exceeds six volumes per 10,000. "When the carbonic acid amounts to seven volumes, a want of freshness is observed on entering. When nine, ten, or more volumes are present, the organic odor becomes manifest" (Smart). We know, of course, that this volume, or even double the quantity, of carbon-dioxide is not in itself harmful, but as it goes hand-in-hand with an increase of organic matter it is an index of the amount of organic impurities, and its estimation, according to Smart, affords the best means of testing the efficiency of the ventilation. Our object should be, therefore, to supply a sufficient amount of pure air so that the volume of CO_2 may not exceed six volumes per 10,000. From careful calculations (see Dr. Smart's excellent treatise on *Air*, p. 152, Vol. I.) it has been found that in order to accomplish this result, an average adult requires about 3,000 cubic feet of fresh air per hour. It is evident that the supply of fresh air can be introduced only by a movement of the air, which is brought about either by a diffusion of the gases or by the difference in weight of masses of air of unequal temperature and the pressure resulting therefrom. It is well known that gases have the property of penetrating or spreading and mingling with others in every direction, and this diffusion takes place through all porous substances, even a

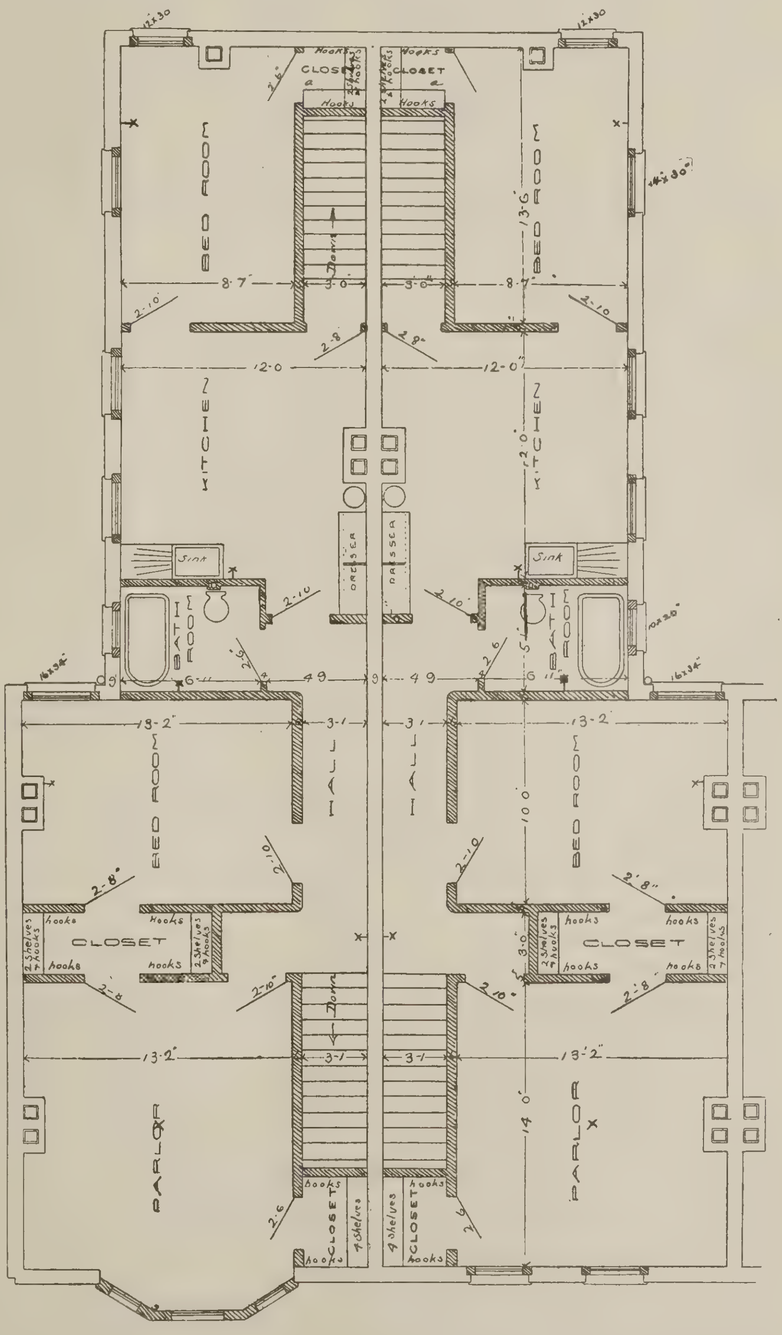

Fig. 2714.—Second-Story Plan of Sanitary Houses for Wage-earners in the City of Washington.

dry brick or stone wall. If it were not for this power of diffusion, CO_2, by reason of its specific gravity, would sink to the lower part of the room.

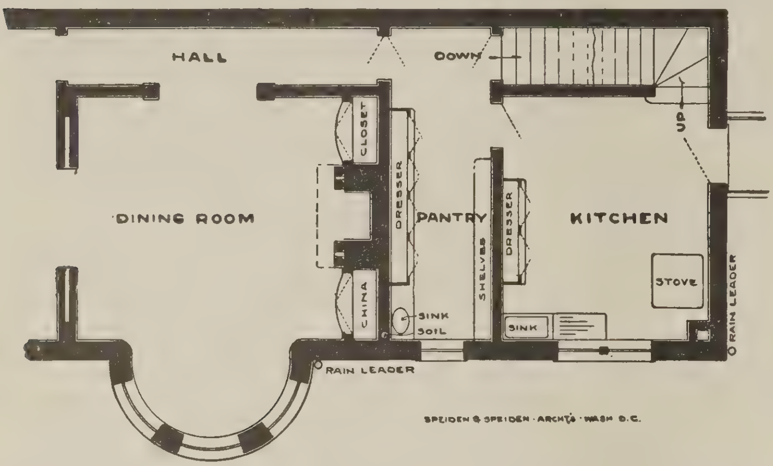

FIG. 2715.—First-Story Plan of a Corner House Showing Location of Pantry, Kitchen, and Dining-Room.

An unequal temperature produces a difference in weight of masses of air. When air is heated it expands; a volume of hot air is consequently lighter than the same volume of cold air. The warm air rises, and to restore the equilibrium the cold air rushes in to occupy its place. This is exactly what takes place in nature. The sun supplies the heat and the air currents, or winds, are thus produced, which in turn serve as powerful ventilating agents in our habitations. The winds act chiefly by perflation, *i.e.* by setting masses of air in motion, driving them onward by an irresistible *vis à tergo;* they also exert an aspirating effect, for when passing horizontally over chimneys or tubes placed at right angles to their course they cause a diminution of pressure within them, the air being practically sucked out, other air from below rushes up to fill the vacuum, and thus an upward current is produced. We see therefore, how ventilation, which means the removal and dispersion of bad air and the introduction of fresh air, may be brought about by all these factors which operate to a greater or less degree in what is commonly called

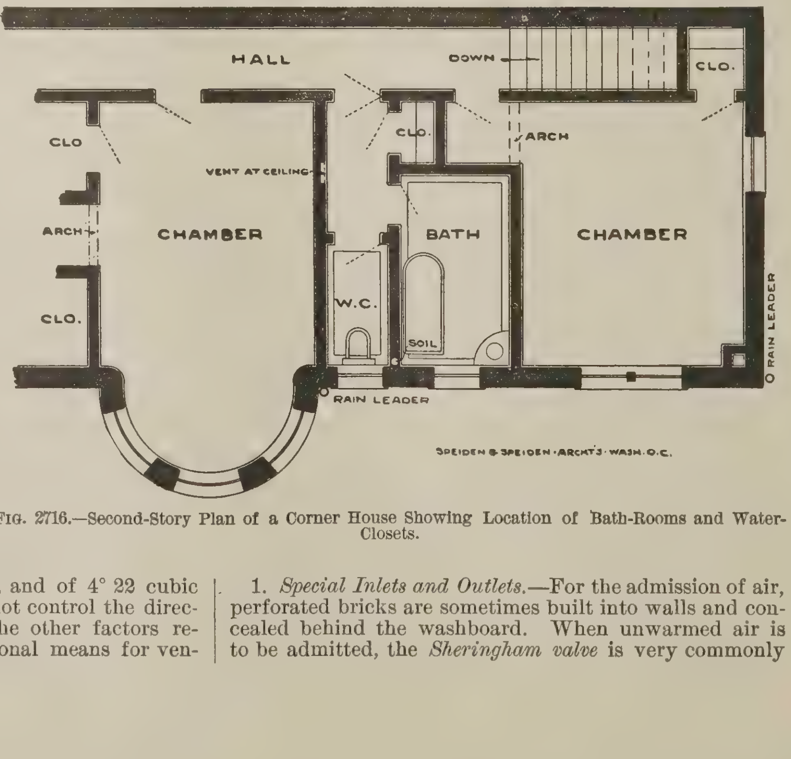

FIG. 2716.—Second-Story Plan of a Corner House Showing Location of Bath-Rooms and Water-Closets.

Natural Ventilation, and which is usually sufficient when each occupant has 1,000 feet of cubic air space and the walls of the house are porous or contain numerous crevices near the doors and windows, and the difference between the inner and outer door temperature is considerable and the winds strike the walls directly or pass with great velocity over chimney flues and other openings. Professor Pettenkofer has shown that by these natural means his library, having a capacity of 75 cubic metres, received hourly at a difference of temperature of 20° 92 cubic metres of fresh air, of 19° 75 cubic metres of fresh air, and of 4° 22 cubic metres of fresh air. But as we cannot control the direction and force of the winds, and the other factors referred to, we should provide additional means for ventilation, and one of the simplest and most efficient plans is to flush the room with fresh air by opening windows or doors on opposite sides of the room. No other method can take the place of this periodical airing for a thorough ventilation of the dead corners and the removal of an immense amount of dust. The objection to this method are the cold draughts in winter, and it should therefore be relied upon chiefly in summer or during the absence of the occupants. In rooms heated with direct radiation, the fresh air should be admitted above the heads of the occupants, either by means of a register in the wall or by the insertion of a louvered or swinging window pane (Fig. 2718) in one of the windows, an upward direction being given to the air so that it may impinge on the ceiling, mix with and be warmed by the heated air in this situation, fall gently into all parts of the room and be gradually removed by means of the chimney flue or any other outlet. Another simple plan is to bore standing holes in the bottom rail of the window sash, or to insert a "Pullman Ventilator" in the bottom rail of the lower sash, or to employ the "Bury Ventilator," which consists of a wooden block interposed between the bottom of the lower sash and the frame. The air passes into the room through the openings in the block which, as in the "Pullman Ventilator," point upward. The separation of the sashes caused by the block also adds to the fresh-air inlet. The use of these devices practically invades the domain of and brings us to the consideration of

Artificial Ventilation, which may be secured by providing, 1. Suitable inlets and outlets; 2. By extraction by heat, or the creation of a decided difference between the inner and outer temperature, and 3. By propulsion and aspiration.

1. *Special Inlets and Outlets.*—For the admission of air, perforated bricks are sometimes built into walls and concealed behind the washboard. When unwarmed air is to be admitted, the *Sheringham valve* is very commonly

used. In this apparatus (Fig. 2719) the air passes through the walls by means of a perforated iron plate and is then directed upward by a valved plate with side checks. This plate being hinged is capable of being more or less completely closed by a balanced weight; it usually measures three by nine inches. *Watson's tube* has two chambers placed alongside of each other, one serving as an inlet and the other as an outlet (Fig. 2720). *McKinnell's ventilator* consists of two cylinders, one inside the other, and of different lengths; the longer tube projects above and below and serves to conduct the impure air, while the outer cylinder having a larger sectional area serves as the inlet. The outlet is protected on the top with a cowl; both tubes can be regulated by valves. They are especially useful for the ventilation of one-story buildings, churches, theatres, kitchens, and pavilion hospitals. The gas burner may be placed immediately under the extracting tube; as the warm air escapes through the inner tube, a corresponding volume is admitted through the interspace between the two cylinders (Fig. 2721).

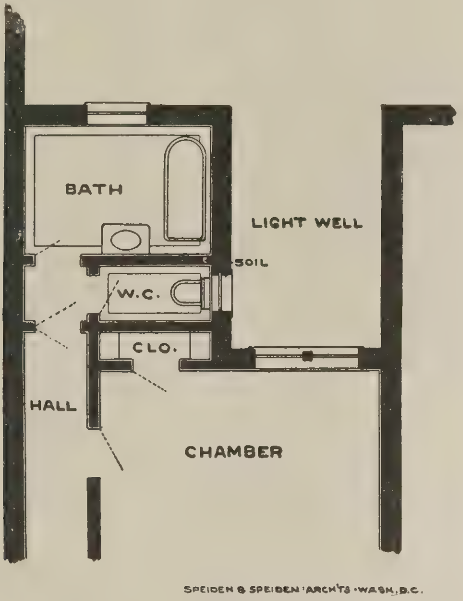

FIG. 2717.—Second-Floor Plan Showing Location of Bath-Rooms, Water-Closets, and Chambers on an Inside Lot.

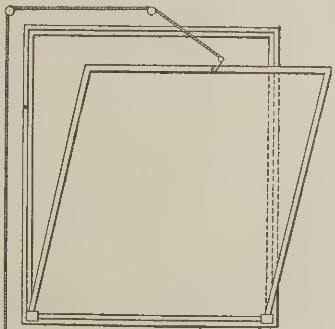

FIG. 2718.—Swinging Window Sash. (Munson.)

The *Ridge Ventilators* consist (Fig. 2722) of openings through the ceiling and roof of one-story buildings, with louvered sides and ends protected with a small roof; the opening of the air shaft in the ceiling is usually provided with a movable shutter to regulate the outlet. The fresh air is admitted by inlets running underneath the floor between the joists and discharging through a register near the stove, or it may be admitted by Sheringham's valves. Of the various methods used in artificial ventilation which contemplate a change of the weight of air without heating, attention is again directed to the perflating and aspirating effects of winds, which are so extensively utilized in the ventilation of ships, and are equally applicable to habitations. Here a large cowl is placed so as to face the wind and the air is thus driven below through a large pipe, whilst another cowl placed to back the wind acts as an aspirator to draw the bad air from below. A great many contrivances seen in connection with house ventilation, some with rotating cowls, others with fixed vanes, are based on this principle (Figs. 2723, 2724, 2725).

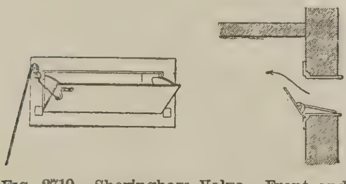

FIG. 2719.—Sheringham Valve. Front and sectional view. (Munson.)

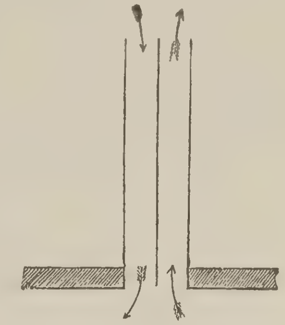

FIG. 2720.—Watson's Tube. (Munson.)

2. *Extraction by Heat.*—The simplest way to produce a difference between the temperature of the inner and that of the outer air is by heating the room by means of a stove or open fireplace, both of which will serve to extract the foul air and secure a thorough renewal of air. In some instances, the outlet can be placed in a separate flue next to the chimney flue; the latter being warmed creates an upward current. Gas jets and lamps may be used in connection with shafts used for the extraction of air by heat (Fig. 2726).

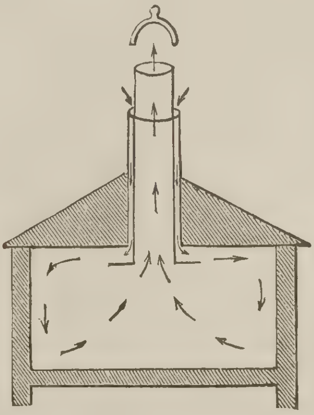

FIG. 2721.—McKinnell's Circular Ventilator. (Munson.)

3. *Propulsion and Aspiration.* — Another system especially adapted for large public buildings is to set the air in motion by the use of fans or air propellers. In other words, the fresh air is forced into and distributed throughout the building while another fan exhausts the foul air. These fans are set in motion by water, steam, electricity, or other motive power. This method presents several advantages: the amount of air delivered and the rate of movement can be regulated with nicety, the entering air can be taken from any desired pure source and can be filtered, washed, warmed or cooled. The Madison Square Theatre, in New York City, according to Dr. D. F. Lincoln (Parkes' "Hygiene," vol. ii., p. 472), is one of the best ventilated buildings of its class. The air is taken at a tower above the roof; is filtered through a conical bag of cheesecloth forty feet long suspended in

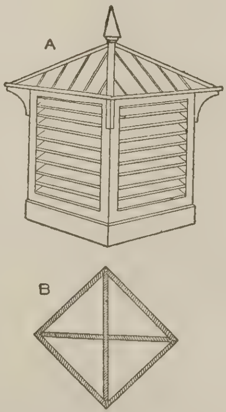

FIG. 2722.—*A*, Muir's Ventilator; *B*, transverse section of same.

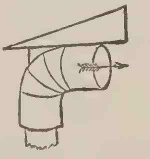

FIG. 2723.—Rotating Cowl for Aspiration. (Munson.)

the tower; it is heated by steam in winter and cooled in summer by passing over ice; heating, cooling, and distributing take place in the basement. One fan at the foot of the tower forces the air into the audience hall, another on the roof exhausts it. The doors and windows are kept closed. The air is introduced by pipes running under the risers; an opening in the riser at each seat discharges a forward current with a velocity of two and one-half feet per second; other jets enter at the front of the footlights and below the balconies the exits are chiefly under the balconies, so that there is a general movement away from the stage. For large buildings, the "Wing disc fan" (Fig. 2727) is usually employed; a four foot fan using one-horse power delivers about 500,000 cubic feet of air per hour, while the larger sizes of the "Blackman wheel," according to Munson, are said to give about 12,000 cubic feet of air per minute (Fig. 2728).

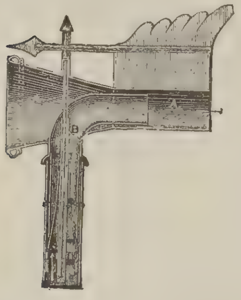
FIG. 2724.—Banner's Rotating Exhaust Ventilator. (Munson.)

Hydraulic ventilators are extensively used during the summer months in Germany; they consist of U-shaped pipes containing spray nozzles under high pressure; the air is sucked in and propelled by the falling spray, the water collecting at the bottom and being discharged by a drain pipe. According to the degree of temperature of the water, the air may also be cooled by this method (Fig. 2629).

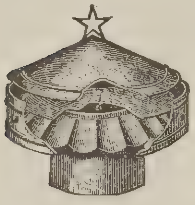
FIG. 2725.—Star Ventilator.

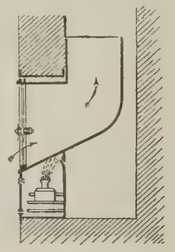
FIG. 2726.—Foul-air Outlet.

General Rules to be Observed in Ventilation.—1. The object of ventilation being to improve the air of the house, we should be sure of the purity of the incoming air. It should not be brought through underground ducts, nor from any point likely to be contaminated by sewer air or other noxious gases. The indication is plainly to select the safest spot for inlets; the inlets should be provided with valves to regulate the amount and protected with fine wire gauze or Hessian jute to exclude vermin and dust. Whenever practicable the air should not only be filtered, but also washed by means of a fine spray in its passage through the inlet. If the fresh air is too cold, it should preferably be warmed before entering the apartments by means of ventilating stoves or grates, or a central system of heating by furnace, steam, or hot water.

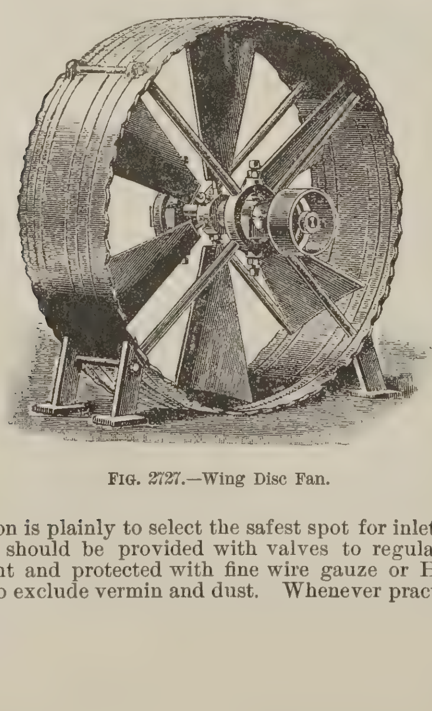
FIG. 2727.—Wing Disc Fan.

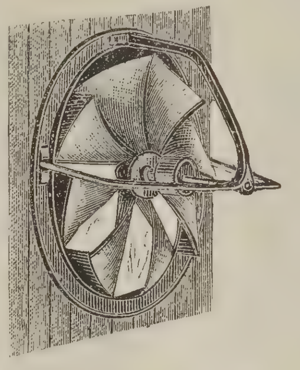
FIG. 2728.—Blackmann's Wheel.

2. The superficial area of outlets should be at least as large as that of the inlets, and in order to insure renovation of air with the least amount of draught, the inlet and outlet openings should not be placed directly opposite but diagonal from each other. It is desirable to place the inlets about the middle height of the rooms and the outlets near the ceilings; they should be supplied with registers to regulate the amount.

3. Since every adult requires 3,000 cubic feet of fresh air, it must be our aim to see that this amount is supplied without discomfort to the occupants. The air of a room cannot be changed oftener than three times in one hour in winter without causing a disagreeable draught; hence every occupant should have a cubic air space of 1,000 feet. Finally this air space must not be furnished in height at the expense of superficial or floor space, for the reason that organic matters are not equally diffused but tend to accumulate in the lower strata; consequently excessive height (*i.e.*, over twelve feet) does not mean a corresponding dilution. In spite of overwhelming clinical evidence, the question of proper air and floor space in prisons, lodging-houses, barracks, and even hospitals has not been practically settled, and the standard adopted is far below the amount required.

In conclusion, it should be distinctly understood that no amount of artificial ventilation can render thorough and frequent house-cleaning unnecessary, or the precautions for the exclusion of contaminated air superfluous, nor can ventilation in winter be maintained without the expenditure of considerable fuel.

Heating.—The necessity for artificial heat whenever the temperature falls below 70° F., notwithstanding the fact that a healthy adult gives off hourly 88 heat units, is fully recognized, and hygiene requires that this artificial heat should be supplied as uniformly as possible, and that the air of habitations, instead of being vitiated by the products of combustion, should be improved by the heating apparatus.

Fuel. — For this purpose materials containing carbon and hydrogen, 1 gm. of which is capable of evolving during combustion respectively 8,080 and 34,462 small calories, are used. Putzey's estimates of the heating value of various kinds of fuel are as follows:

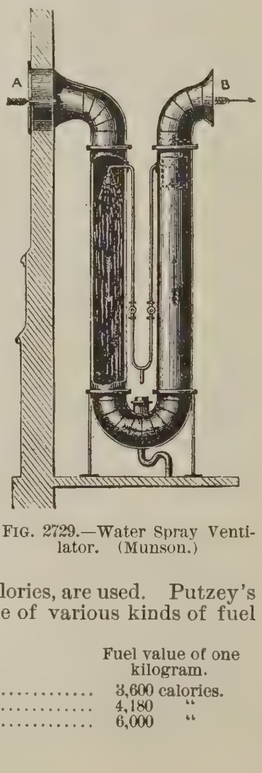

FIG. 2729.—Water Spray Ventilator. (Munson.)

Fuel.	Fuel value of one kilogram.
Dry wood	3,600 calories.
Lignite	4,180 "
Coke	6,000 "

House Sanitation.

Fuel.	Fuel value of one kilogram.
Charcoal	7,000 “
Bituminous coal	7,500 “
Anthracite	8,000 “
Petroleum	17,176 “
Illuminating gas per cubic metre	7,700 “

Of the foregoing fuels, white ash, Lehigh anthracite coal, and gas unquestionably permit of the most complete and ready oxidation of the carbon and hydrogen, which elements supply the heat.

The products of combustion are chiefly carbonic acid and water, although sulphurous vapors and arsenical fumes may be evolved in the combustion of mineral coal. If the amount of oxygen is insufficient for free combustion carbon monoxide, fine particles of carbon in the form of soot, tarry matters, and carburetted hydrogen also escape. The smoke under such circumstances is therefore a mixture of C, CO, CO_2, H_2O, C_2H_2 and may also contain sulphurous and arsenical vapors.

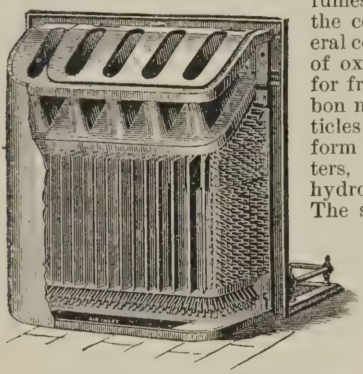

FIG. 2730.—Jackson's Ventilating Grate, Back View. The outer casing is cut away to show space and surface for warming the incoming air.

Rooms may be warmed separately by stoves or fireplaces; this is called *local heating* in contradistinction to the system of *central heating* in which the heat is supplied to a number of rooms or the entire building from a central plant. The latter system offers so many advantages that it is rapidly superseding every other method, at least in cities. The majority of houses in rural districts, however, are still warmed by open fireplaces and stoves. Fireplaces are niches in the chimney supplied with grates in which combustion may be maintained and the products are rapidly carried off through the chimney. The room in this instance is warmed by *radiant heat*, which means the passage of heat from warm bodies to cold ones without raising the temperature of the intervening air directly; the latter is warmed by convection from heated objects. A uniform temperature cannot be maintained by the exclusive use of an open grate, and though a most excellent ventilating apparatus, it is too powerful to be wholesome, and is moreover quite wasteful, as five-eighths of the heat generated escapes up the chimney. The latter objection has been in a measure overcome by controlling the chimney current by a damper, and by a proper construction of the grate and fire-back. For this purpose the width of the grate at the back should be about one-third the width in front facing the room; the side walls of the fireplace should join the back at an angle of 45°, so as to throw as many heat rays into the room as possible, and for similar reasons the whole fireplace should be brought well forward into the room. To minimize these defects, an attempt has been made to surround the back and sides with a space through which air can pass and be warmed by the heat that would be otherwise wasted. An opening below admits fresh air into the chamber where it is warmed and escapes through an opening into the room above the mantle. The Galton, Jackson, and Joly ventilating grates are all constructed on this principle and are therefore a combination of hot air and fireplace heating (Fig. 2730).

Stoves.—There are an endless variety of stoves in which either wood, coal, gas, or petroleum is burned, and in which from seventy-five to eighty per cent. of the fuel is utilized. The great distinction between these and open fireplaces is, that the air which comes in contact with the heated surface is warmed, expands and rises, and its place is taken by a cold air; the currents of warm air circulate through the room and thus every part is equally heated. It is essentially heating by convection, although a very hot stove also supplies radiant heat. Stoves are made of wrought or cast iron, terra-cotta, porcelain, and soapstone; some are ordinary closed stoves, while in others provisions are made for the admission of fresh air from without, which is made to circulate through the stove without coming in contact with the products of combustion, and after being thus heated passes into the same room or the room above, as in our lathrobes, ventilating grates, or the "Cortland Howe" ventilating stove (Fig. 2731). The principle of introducing fresh air can be applied by running a fresh-air inlet from the outer air to near the stove and surrounding the latter with a jacket of sheet iron. The inlet and corresponding outlets should be provided with registers. This is a very simple and effective method of heating and ventilating rural school-houses, etc.

Since gas, both natural and artificial, and coal oil are being extensively used in this country for both heating and cooking purposes, it may be stated on the authority of Notter and Firth that when the combustion is complete and the ventilation is sufficient for the ordinary effects of respiration, their use is not fraught with danger, especially when the more improved patterns are used; but the larger oil stoves or gas stoves which burn more than five feet of gas per hour should be provided with a flue to carry the products of combustion to the outer air. The ordinary gas logs set in fireplaces or the "Backus portable steam radiator" for use with gas should be preferred.

Heating by electricity possesses many hygienic advantages, but the excessive cost has so far prevented its general use.

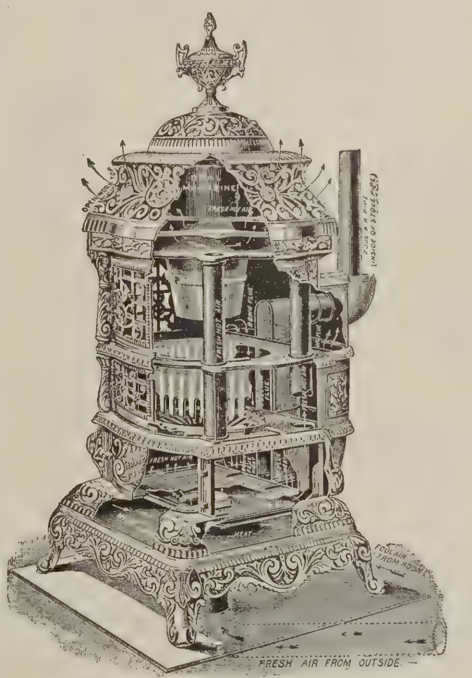

FIG. 2731.—Cortland Howe Ventilating Stove.

Central Heating (*Furnace*).—A very common way to heat a modern dwelling is by the use of a hot-air furnace. In such a case a furnace of wrought or cast iron, brick or soapstone is placed in the basement; the fresh air is admitted from a pure source into the air chamber of the furnace where it is heated and conducted in suitable-sized flues to the different rooms and stories of the house. According to Mr. Edward S. Philbrick ("Man. of Pract.

Hygiene," Parkes, vol. ii., p. 466) a house of more than three large rooms on the floor, however, with one or two stories of rooms above, cannot be properly heated by only one furnace, as it is almost impossible to conduct heated air more than six feet in a horizontal direction from the furnace. The combination of a hot-air furnace and open fireplaces is believed to be a very sanitary way of heating a house, because provision is thus made for both inlets and outlets; the latter are often neglected. An open fireplace is very useful in drawing the furnace air down to its own level, even when there is no fire actually burning in it. All this is important, for apart from the fact that outlets should exist for the extraction of foul air, a windward room cannot be warmed because the furnace air refuses to enter it, and the remedy for this is the open fireplace, or the opening of a chimney flue in the room. Flues from furnaces supplying different rooms sometimes draw against each other, especially when the supply from below is not sufficient for all, either because the fresh-air inlet to the furnace is too small or because after it has been closed in a high wind some one has neglected to open it (Lincoln).

The objection to cast-iron furnaces and stoves is that carbon monoxide is believed to escape through invisible fissures in the plates and joints, while the heaters are red hot; hence they should be lined with fire clay; this precaution may not be necessary for the escape of CO, but it will improve at least the quality of the heat. Soapstone furnaces are highly praised for the quality of the air. Since all heaters are liable to render the air too hot and dry, they should be provided with evaporating pans, or, what is even preferable, a larger heater should be chosen which will not have to be raised to red heat and at the same time furnishes a larger volume of warmed air. If the air is superheated it acquires a peculiar odor, probably due to charring of organic dust; it also becomes very dry and irritating owing to the rapid evaporation of moisture from the skin and mucous surfaces of the inmates and in consequence is apt to produce catarrhal affections, conditions which do not prevail when the temperature of the air delivered does not exceed 90°. There is also economy in running a stove or furnace at a moderate rate, and a reserve should be on hand for colder weather. Dampers in the smoke flues of heaters are always objectionable; the joints of the draft doors should be so good that opening and closing of the lower door or slides is sufficient, but as long as these joints are imperfect, dampers are a necessary evil.

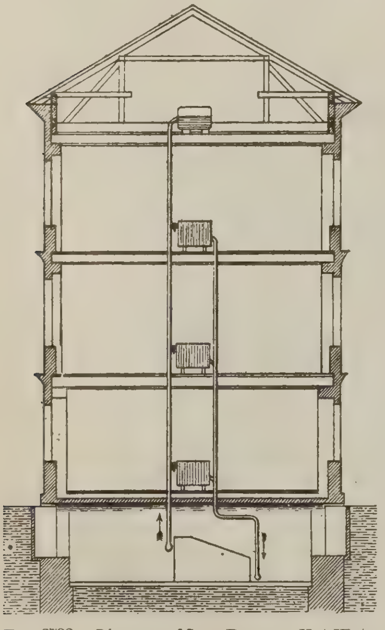

FIG. 2732.—Diagram of Low-Pressure Hot-Water System. (Munson.)

Heating by Hot Water is now extensively employed in modern homes and even larger buildings and while more expensive than the first cost of hot-air furnaces and a steam-heating plant, the advantages are economy in fuel and repairs; the temperature is more agreeable and the heat can be conducted to any desired point. In the *low-pressure system* large pipes, generally four inches in diameter, are connected with a boiler so as to provide a complete circulation. The water after being heated circulates through the pipes and radiators, parts with more or less of its heat to the air, *i.e.*, heating by convection, and returns to the boiler. At the highest point of the system an expansion tank is placed, and a small escape pipe is carried into the outer air to give vent to steam and hot air. The water rarely ever attains a higher temperature at any part of the system than 200° F. (Fig. 2732).

In the *high-pressure system* the pipes are smaller, about one inch in diameter, but sufficiently strong to withstand the pressure incident to a very high temperature, as from one-tenth to one-sixteenth of the coils are exposed directly to the heat of the fire. The water being completely enclosed from the outer air, attains usually a temperature of 300° F. and circulates more rapidly; provision is made for expansion by larger pipes at the top of the system. With the low-pressure system about twelve feet of radiating surface for every 1,000 cubic feet are required to raise the temperature of the room to 65° F. at zero weather, while with the high-pressure system eight or nine feet are sufficient. The volume of water in the high-pressure system is very much less and is heated therefore more quickly than in the low-pressure system, but it will also cool more quickly, and on the whole the advantages are decidedly in favor of the low-pressure system, because the temperature is more uniform and there is no danger from explosions or superheated pipes.

Steam Heating is employed in many public and private dwellings and the waste steam of locomotives is utilized in the warming of cars, ships, and factories. The methods have been perfected and the danger from explosions reduced to a minimum; nevertheless steam plants, as well as other central heating apparatuses, require careful planning and intelligent supervision. Steam heat, like furnace heat, is apt to be excessive in mild weather, but the temperature can be regulated by arranging multiple coils or radiators, which can be shut off in sections. In every case the calibre of the radiator should be larger than the supply pipes so as to favor condensation and consequent liberation of latent heat. Provisions must also be made for the rapid return of the condensed vapor to the boiler by means of return pipes, since any obstruction to the flow of the return steam interferes with a free and rapid circulation and causes not only defective heating but also a most disagreeable thumping noise.

In connection with either hot water or steam heating, we recognize three methods: (1st) the direct; (2d) the indirect; and (3d) the direct-indirect. In the direct system the radiators are placed in the room without any special provisions for ventilation; in the indirect system, the coils or radiators are placed in a suitable chamber in the basement into which fresh air is admitted and from which the heated air is distributed to the different rooms by suitable inlets and outlets. This plan answers very well for ordinary dwellings, but for larger buildings arrangements must be made to force the heated air where wanted, and this is accomplished by the *exhaust system*, or the *plenum system*. In the former the air is exhausted by suction and the pressure of the atmosphere is relied upon to replenish the fresh air, while in the plenum system the air is forced into the room by special fans, and is preferable because the purity and volume of the air can be regulated in the manner already referred to under Ventilation. In the *direct-indirect* system the radiators are placed under the windows and the fresh air is admitted from behind them and is warmed by its passage over the radiators. The fresh-air inlets are controlled by a key in the room connected with a register outside in order to regulate the amount of fresh air, while the foul air is discharged by suitable outlets. The air in steam- and hot-water heated apartments may also become excessively dry and evaporating pans are almost as essential as with furnace heat. With automatic thermoregulators, it is possible to maintain a uniform temperature, and on the whole we may conclude that the indirect and direct-indirect systems—

combining, as they do, a central system of heating with proper ventilation—are the most sanitary. The use of steam gives perhaps more satisfactory results in cold climates than the hot water, but either method is preferable to hot-air furnaces.

Lighting.—Apart from the hygienic importance of sunlight on metabolism and its destructive effect on germ life, every room, whether used for dwellings, workshops, schools, etc., should be so well lighted by windows that the eyes need not be strained even on a cloudy day.

Natural Lighting.—The area of windows exclusive of sash frames should be at least one-sixth or preferably one-fifth of the floor space, and in order that the light may penetrate the deeper portions of the room, the windows should almost reach to the ceiling. After providing the windows we should, of course, not shut out ninety per cent. of the light by blinds and draperies; but if the light is too glaring it may be softened by white, cream, or light gray shades; the color of the window panes should always be perfectly transparent; plate glass possesses the advantage of warmth and durability. The difficulty of securing a sufficient amount of daylight in buildings located on narrow streets surrounded by tall buildings has been partly overcome by glass building blocks 8×6×2½ inches, with an air chamber in the centre, used instead of brick or stone in connection with steel frame construction, but more particularly by the introduction of prisms, which refract and diffuse the light throughout a room that would otherwise be illuminated but partially or not at all.

Artificial light, no matter how obtained, differs from daylight in this, that it does not furnish a pure white light; the prevailing rays are red, yellow, or violet, and the effects of a yellowish-red or violet-blue are produced. Whatever difference of opinion there may be as to the color best suited to our eyes, we know that our vision is most perfect under the influence of a white light, and this ought to be a good criterion. One of the disadvantages of all low-power illuminants is that the light is never as bright as daylight, involving therefore closer application of the eyes and consequent strain of the muscles of the eyeball. These remarks are hardly applicable to the electric arc-light and the Welsbach gas-burner, the rays of which, like the direct solar rays, may indeed be so glaring as to cause undue irritation of the retina. Another harmful effect of artificial illumination is the unsteady or flickering character especially seen in the electric arc-light, and which on account of the abrupt changes is likely to irritate the retina; another disadvantage is that the ordinary illuminants, except the electric light, tend to vitiate the air by the products of combustion and also affect the temperature and humidity of the air by the heat evolved. The requirements of a hygienic light are that it should be as near as possible the color of sunlight, sufficiently ample, but not too glaring; it should be steady and, instead of deteriorating the air, it should as far as practicable be utilized to improve the air; nor should the heat evolved be sufficiently intense to be a source of discomfort to the inmates in warm weather.

From this table we conclude that the electric arc-light is the most suitable for lighting of streets and squares, the electric incandescent light is best suited for public and private habitations, including also steamers, powder works, and mines. It is in every way superior to gas and other illuminants, because there is no danger from fire, there are no products of combustion, hence no pollution of the air, nor are the temperature and humidity of the rooms affected to any perceptible extent. These advantages over gas are of special importance to the inmates of buildings where the question of fresh air and temperature play an important rôle; hence we can readily appreciate that banks and other institutions find it profitable to install electric lighting and save time and money by the prevention of sickness among their employees. Next to electric light, gas, especially in connection with a Welsbach or Siemens burner, offers the next best choice; in the absence of either, kerosene with a high flashing point should be preferred over other illuminants. The flashing point of refined kerosene is defined as the temperature at which a sample of the oil commences to give off sensible quantities of inflammable vapor; it should not be less than 100° F. and a higher temperature is preferable. Explosions may occur in lamps when from any cause the vapor over the oil in the reservoir is lighted by a spark, as for instance when the wick is extinguished by blowing over the chimney and is then depressed in a smouldering condition, or when the chimney of the lamp is broken. The Duplex and Rochester burners and many other safety lamps have reduced these dangers to a minimum. The dangers from the inhalation of carbon monoxide from leaky gas fixtures and pipes are especially great when water gas is used, on account of the total absence of odor. Of the various gas burners, the Welsbach, Siemens, and the argand burner enclosed with a chimney give the best results. Wherever practicable, provisions should be made to carry the products of combustion to the outer air, and thereby aid in ventilation.

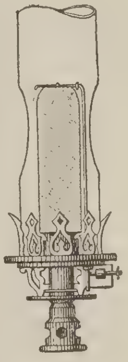

FIG. 2733.—Welsbach Burner.

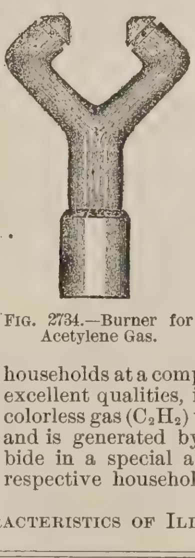

FIG. 2734.—Burner for Acetylene Gas.

Acetylene gas has recently come into deserved prominence, and as it can be generated for individual households at a comparative slight expense, and has many excellent qualities, it is likely to grow in favor. It is a colorless gas (C_2H_2) with a characteristic unpleasant odor, and is generated by the action of water on calcium carbide in a special apparatus, suited to the needs of the respective household or building. Munson states that

SUMMARY OF THE MOST IMPORTANT CHARACTERISTICS OF ILLUMINATING AGENTS.

Illuminants.	Quantity consumed.	Color.	Candle power.	Oxygen removed. Cubic feet.	CO_2 produced.	Moisture produced. Cubic feet.	Heat calories produced.	Vitiation equal to adult.
Tallow candles	2,200 grains.	Red yellow	16	10.7	7.3	8.2	1,400	12.0
Sperm candles	1,740 "	"	16	9.6	6.5	6.5	1,137	11.0
Paraffin oil lamp	992 "	"	16	6.2	4.5	3.5	1,030	7.5
Kerosene oil lamp	909 "	Light red yellow	16	5.9	4.1	3.3	1,030	7.0
Coal gas, No. 5 batwing burner	5.5 cubic feet	" "	16	6.5	2.8	7.3	1,194	5.0
Coal gas, Argand burner	4.8 "	" "	16	5.8	2.6	6.4	1,240	4.3
Coal gas, Siemens' regular burner	3.2 "	Yellowish-white	32	3.6	1.7	4.2	700	2.8
Coal gas, Welsbach	3.5 "	White	50	4.1	1.8	4.7	763	3.0
Acetylene	1.0 "	"	50	....	2.0	....	....	3-6
Electric incandescent light	0.3 "	"	16	0.0	0.0	0.0	37	0.0
Electric arc-light	....	Blue violet	100	....	0.0004	....	....	....

"a generator capable of thoroughly lighting a company barrack or post hospital need not be greater in bulk than a hogshead, while one capable of illuminating a field hospital of one hundred beds is not larger than a pork barrel." The gas requires a special tip and combustion is usually complete (Figs. 2734 and 2735).

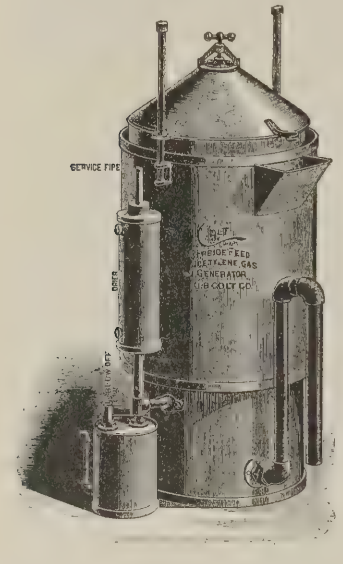

FIG. 2735.—Large Size Acetylene Generator. (Munson.)

Water Supply.—In cities furnished with a general water supply, every floor should be provided with water taps, not only for convenience, but also for greater safety in case of fire. In isolated houses and villages without a general supply or a good spring in the vicinity, our choice will be between artesian, cistern, and well water. On general principles preference should be given to artesian water. (See article on *Water*.)

House Drainage.—The object of the sanitarian is to remove as rapidly as possible all excreta and refuse from habitations, so that the air, water, and soil shall not be made impure. In any event the accumulation must in no case extend so far as to render putrefactive changes evident to our sense of smell. The various methods for the disposal of sewage will be discussed in a separate article, and for the present suffice it to say that the most sanitary disposal of the flow from the water-closets and house drains is a well-devised system of sewerage, which will convey the flow on to farm lands or into the sea, but not into watercourses used for drinking purposes. Since this system begins in the habitations, we shall point out the requisites for proper house drainage, which consist of:

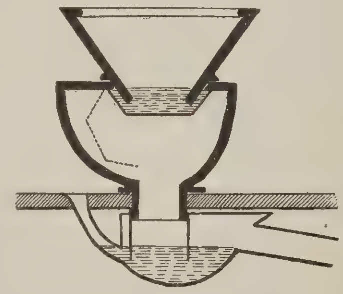

FIG. 2736.—Pan Closet.

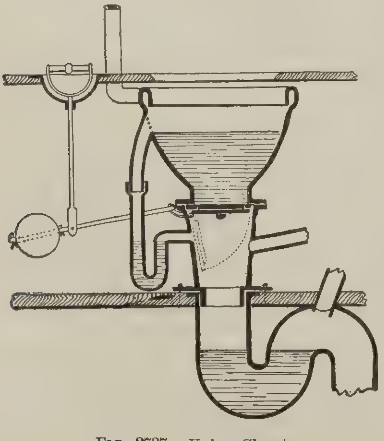

FIG. 2737.—Valve Closet.

1. Water-closets and urinals, wash basins, bath and laundry tubs, and kitchen and slop sinks;
2. A perpendicular pipe known as the soil pipe with which the foregoing fixtures are connected; and
3. The house drain, which is a nearly horizontal pipe, and connects the system with the sewer or cesspool.

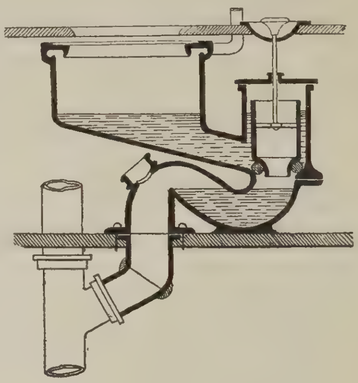

FIG. 2738.—Plunger Closet.

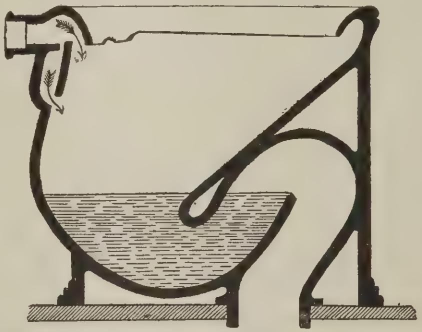

FIG. 2739.—Deluge Closet with Recessed Back. (Munson.)

Water-closets consist of an apparatus for the reception of excreta connected with the soil pipe by means of a suitable trap, and in which water is used to dilute and carry away the excrement deposited therein. They are classified under two heads, viz.: those in which there is no movable apparatus for retaining water in the bowl, and second, those which are supplied with a movable apparatus. Under the first head are included hopper, washdown and wash-out closets, under the second, pan-valve and plunger closets. Space will not permit me to enter into a detailed description of the various patterns, except to say that the pan, valve, and plunger closets (Figs. 2736, 2737, and 2738) are objectionable and should not be tolerated. Among the best forms are the short hopper closets, with a trap which opens into the soil pipe above the floor. This brings the water seal well up in the hopper and reduces to a minimum the surface likely to be fouled above the trap-water. So-called "wash-down" closets are modications of the short-hopper; of these the "Deluge," "Dececo," and the "Century" have given the most satisfactory results (Figs. 2739, 2740, and 2741). All of these fixtures are designed to give a quick and powerful flush of five or six gallons of water from a tank, the siphon of which is put into action by pulling a chain. Where the closet is to be used by servants, children, and others likely to neglect the flushing, the water supply should be made automatic and metred by a waste-saving apparatus. The

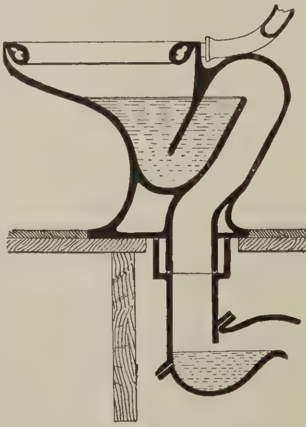

FIG. 2740.—Dececo Closet.

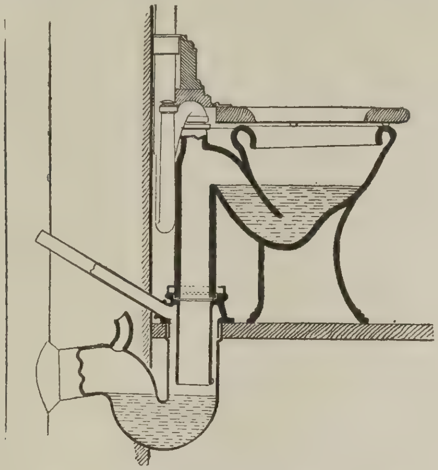

FIG. 2741.—Century "Siphon-jet Closet." (Munson.)

weight of the person on the seat is thus made to lift the valve in the bottom of the tank and when the weight is removed this valve closes and the lower one opens, discharging an ample and definite quantity of water with a sudden dash, which expels all the contents of the hopper below. For public buildings, copious flushes discharged at regular intervals from automatic flush tanks like the "Rogers-Field" are to be preferred. No system should be tolerated which provides for the flushing of the hoppers by faucets, for even if allowed to run for half the time with the consequent waste of water, it does not flush the system like the sudden dash of five or six gallons of water.

Water-closets whenever practicable should be located in a separate room from the bath-room, and preferably in a special projection connected with the house by a well-ventilated lobby; the closet should be provided with a window and other outlets, so that the air may find a ready exit without contaminating the air of adjoining rooms. The exhaust flue already referred to (Fig. 2726) and heated by either a gas jet or lamp is especially indicated in rooms used for water-closets. Each floor of the house, if great convenience is desired, should have such a room and an adjoining room large enough for the bathtub, lavatories, slop sinks, etc. (See plans on page 756.)

Simplicity of the drainage system is of the utmost importance; hence all the fixtures necessary for the comfort of the inmates of the house should be placed in close proximity to the soil pipe, drained and trapped separately into the soil pipe. An error frequently made is to connect a wash bowl waste with a water-closet trap several feet distant by a pipe under the floor, difficult of access and so nearly horizontal as to insure its being soon filled with a deposit of slimy filth. This, like the scattering of fixtures all over the house, is very objectionable. A well-planned, moderate-sized house will show all the bath-rooms, water-closets, pantry, kitchen and laundry fixtures directly above one another and in close proximity to the soil pipe; that is to say, the rooms used for servants' bath-room and laundry in the basement should correspond with the kitchen and pantry on the first floor, and the toilet rooms and water-closets on the upper floors. (See the diagram shown in Fig. 2742.) All the plumbing should be exposed, and since the introduction of nickel-plated pipes the various fixtures present a very attractive appearance. Copper-lined wooden bathtubs and encased wash bowls and water-closets have given way to open elegant and durable fixtures of porcelain, enameled iron or marble, and the ordinary water-closet with hinged seat can be used for a urinal. The bathrooms and other rooms containing plumbing should have an impermeable floor, such as the "granito" floor already referred to, while tile or adamant walls are also desirable.

Urinals should always be of some non-corrosive material, such as china, stoneware, or slate; public urinals should be provided with automatic flushing tanks or a "flush-down spray" (Fig. 2744) and an impermeable floor sloping toward a gutter which discharges into a siphon trap connected with the soil pipe.

Kitchen, pantry, slop sinks, and laundry tubs are usually made of earthenware, porcelain, slate, soapstone, or galvanized iron with or without enamel, and are protected with a strainer to keep the large foreign bodies from obstructing the pipes. Whenever the kitchen and

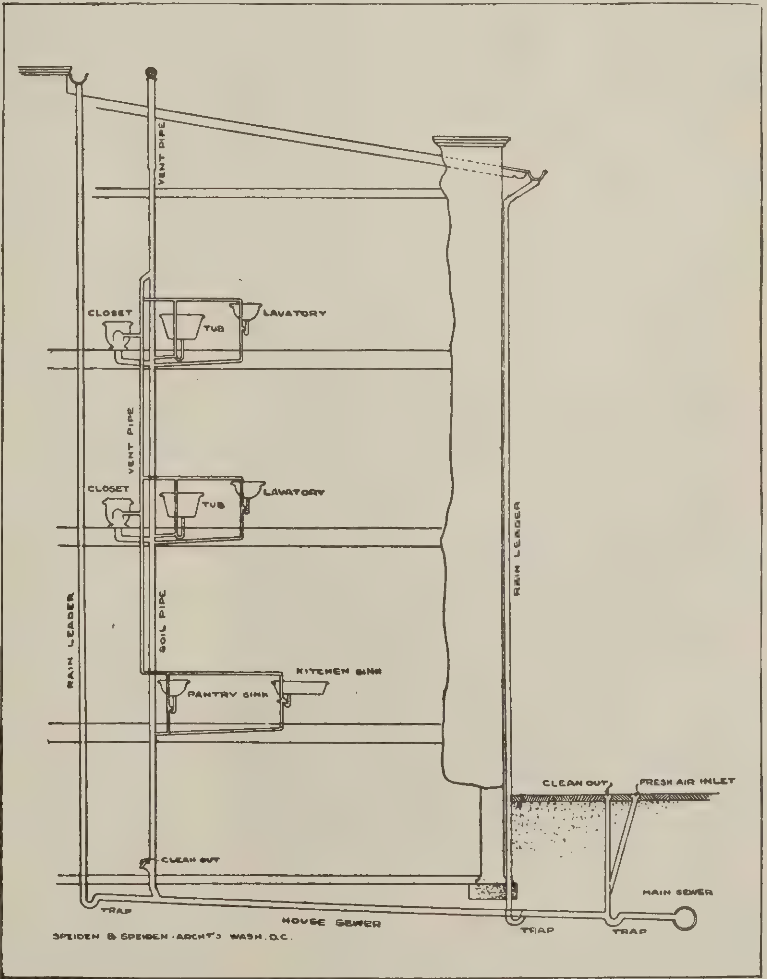

FIG. 2742.—Diagram Illustrating Sewage Plumbing of a House.

pantry drains cannot be provided with a very rapid fall, the congealing of the grease is likely to form a deposit on the inside of the pipe which often obstructs it entirely. To remedy this condition, which will arise no matter how large the drain pipe, the drain should be flushed with a hot four-per-cent. solution of caustic potash or soda several times a week, or, what is far better, so-called "grease interceptors" are placed as near the sinks as possible. The grease congeals in these bowl-shaped stoneware tanks and floats on the surface and can be removed when necessary. The outlet for the waste water being immersed several inches below the surface, the water is allowed to flow off while the grease accumulates on the top of the standing water (Fig. 2745).

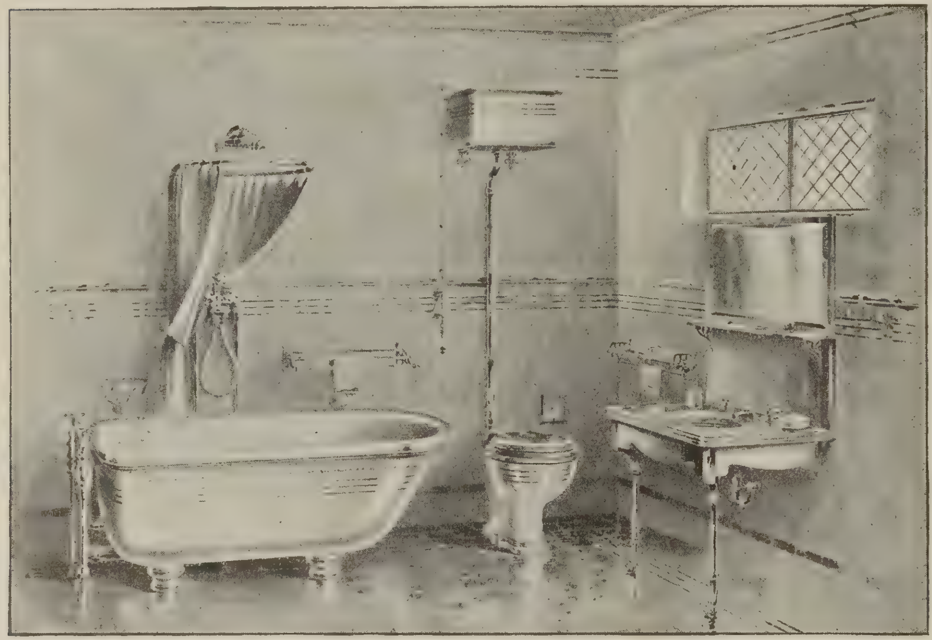
FIG. 2743.—Model Bathroom. (Plate VI.—R, copyright 1900 by the J. L. Mott Iron Works.)

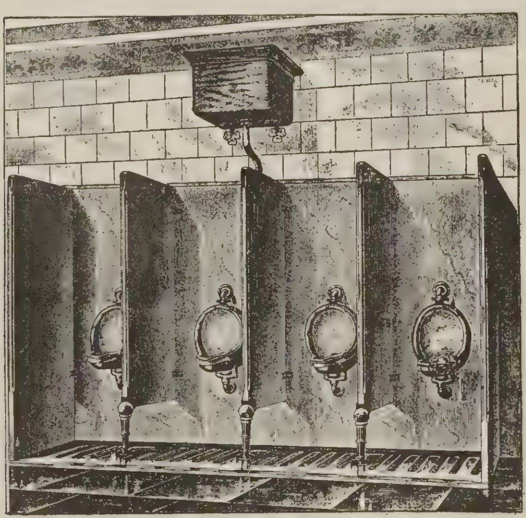
FIG. 2744.—Bowl Urinal. (Munson.)

Soil Pipes.—The soil pipe forms a vertical stack inside of the building, extending from the house drain through the roof where it should terminate ten feet away from all windows and chimneys. The soil pipe receives the sewage from the water-closets and the waste water from all other fixtures; it should never be less than four inches in diameter, made of wrought or cast iron and painted with a coat of tar within and without. Special rules are laid down for the construction of the joints between the different lengths; they may be screwed together, or what is more common caulked with oakum and lead and Spence's metal. Screw joints are preferable. In any event they must be air- and water-tight and free from all defects. The proper security of the soil pipe is a point of importance, for if not perfectly secured it may during the settlement of the walls strain one or more of the connecting joints and produce mischief by leakage. The connection between the soil pipe and house drain should be made by means of a rounded elbow and not by an abrupt right angle (Fig. 2746). At this junction a screw plug should be inserted for inspection and cleaning, as obstructions are most likely to occur at this point.

Traps and Ventilation of Soil Pipes.—It will be readily understood that if the fixtures were simply connected by means of ordinary drain pipes to the soil pipe, the air of the house would certainly be contaminated by sewer air and the more objectionable emanations from the soil and house drains, which are constantly coated with a slimy putrescible mass, giving rise to dangerous and offensive gases.

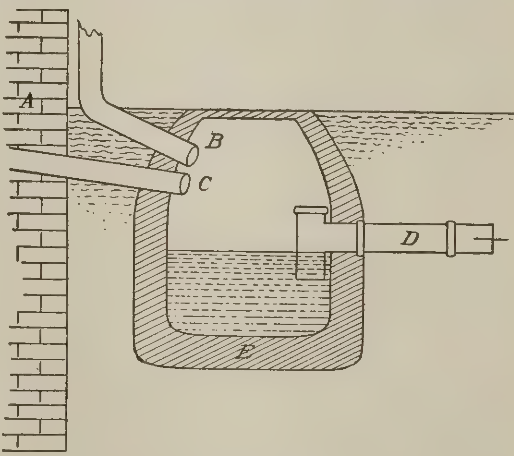

FIG. 2745.—Grease Interceptor. *A*, House wall: *B*, ventilation pipe; *C*, inlet; *D*, outlet.

When houses are artificially heated, this tendency is increased by the diminished density of the air within the house, causing slight inward pressure through all existing openings and fissures. The remedy consists, first, in the use of traps which are certain appliances so constructed as to form a water seal of at least three-quarters of an inch, standing above the highest level of water in the curve of the trap. This water seal prevents the back flow of gases. There are an endless variety of traps in the market, such as the siphon, "Sanitas," midfeather trap, bell traps, etc. (Figs. 2747 to 2753), but of these Figs. 2747, 2748, and 2749 are the simplest and best, because there are no corners or angles for the accumulation of filth and the whole curve is always full of water. The water seal may be broken by evaporation when the fixture is not in constant use; this in warm weather may occur within a few days, and to reduce the danger to a minimum Mr. Putnam invented the "Sanitas trap" which has given excellent results. Evaporation may also be prevented in unoccupied houses by pouring a little oil into the fixtures. It is desirable, however, upon re-occupying a vacated house to flush all the fixtures with water and air the rooms, as sewer air may have entered. Traps may also be emptied by reason of capillary attraction, which is liable to occur if bits of rags and strings have found access to the trap, and one end passes over the further bend while the other remains immersed in the water seal. The water seal may also be broken by a heavy rush of water through it from its own fixture ("*siphonage by momentum*") or by a rush down the soil pipe from a fixture on a higher level, "*siphonage by suction.*" As an additional precaution against the entrance of sewer air and the unsealing of traps by siphonage, the soil pipe and traps should be ventilated. For this purpose the soil pipe is carried above the roof, the top being left open or protected with wire gauze or a ventilating cap, and fresh air is freely admitted to the drain at its lower end on the house side of the trap which connects the system with the sewer. The fresh-air inlet terminates above the ground and must be protected by a perforated iron plate to prevent obstruction, and as the air of the house is generally warmer a constant upward current is thus secured, except when the closet is used, when the current is reversed on account of the sudden rush of water downward through the pipe. For this latter reason and on account of the frequent obstructions placed in the fresh-air inlet by playing children and the obstructions found in the running trap, there has been a disposition to abandon the fresh-air inlet and running trap altogether, and Mr. Charles E. Ball, Inspector of Plumbing of the City of Washington, states that in two outlying districts of the city the concurrence of three conditions—viz.: new clean sewers, recently constructed house plumbing, and the separated location of the dwellings—has justified the omission of the house running trap; indeed, he holds that the objection to open connections with the sewers has little force if the plumbing within each house thus connected has tight joints. The present method of inspections and tests of our plumbing work assure this result in most cities. If the houses are constructed of uniform height, as is usually the case in modern city blocks, or if they are isolated from each other as in suburban localities, emanations from the soil pipe openings cannot injuriously affect the occupants of neighboring premises.

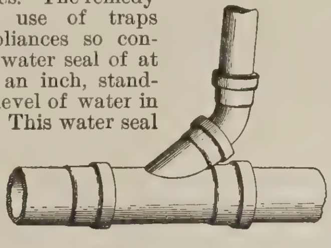
FIG. 2746.—Method of Connecting Soil Pipe with House Drain.

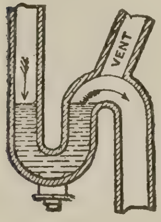

FIG. 2747.—Vented Trap.

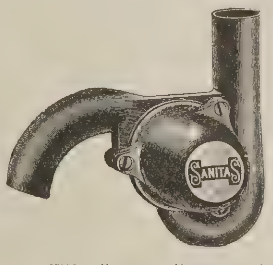

FIG. 2748.—"Sanitas" Non-vented Trap.

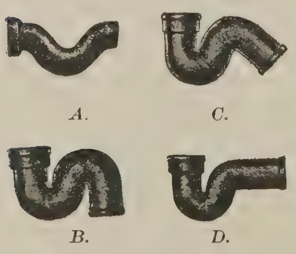

FIG. 2749.—*A*, Running trap; *B*, S-trap; *C*, three-quarter S-trap; *D*, half S-trap.

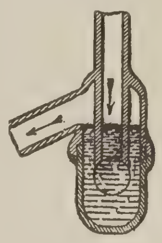
FIG. 2750.—Bower's Trap.

That even more radical opinions than those here expressed are entertained by eminent sanitary authorities is evidenced in a report of the Sewerage Commission of the City of Baltimore, rendered in November, 1896, by Mess. Rud. Hering and Samuel M. Gray, who say:

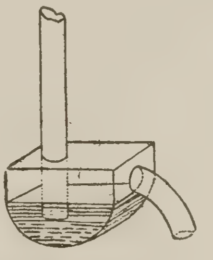
FIG. 2751.—D-Trap. (After Notter and Firth.)

"The problem of sewer ventilation resolves itself into a provision for maintaining a direct communication between the air in the sewers and the atmosphere and in causing the entrance of pure air and its circulation through the sewers to be as free as practicable.

"The most perfect way of accomplishing the above conditions is to ventilate public sewers through the house drains and soil pipes of the buildings, to omit the main trap along the house sewer which also acts as a retainer of foul matter, and to have perforations in the manhole covers of the public sewers.

"In this way an abundance of air can enter the system not only from the outfall, but through the manhole covers and circulate through the sewers and out through every premise sewer to above the roof of the buildings.

"Such a method of ventilation, however, requires that the entire plumbing in the house is planned and constructed by responsible parties, so that the work will be first class. It is also necessary to have the house pipes tested after the plumbing is finished so as to be assured of tight joints. This method has been tried in several cities in our country and is the common one on the continent of Europe, but it is not the usual one in our country, for there is in the minds of many a fear that if the public sewer should be ventilated through the soil pipe of their house, some danger might arise through a leak in their own pipes of contracting a disease, the germs of which are supposed to come from the public sewer.

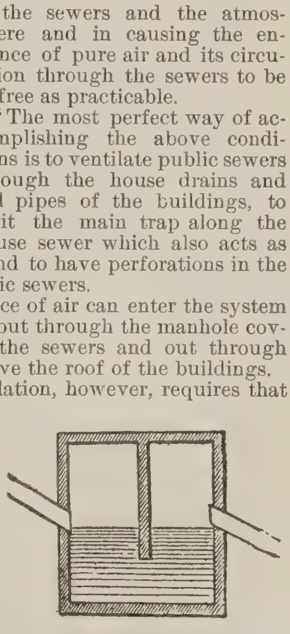
FIG. 2752.—Mid-feather Trap. (Notter and Firth.)

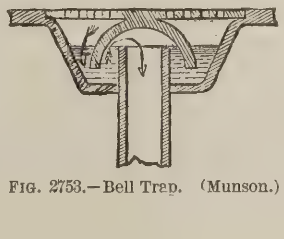
FIG. 2753.—Bell Trap. (Munson.)

"From experience in our country and in Europe, these fears are not well grounded and there are no facts on record to justify them. On the other hand, the advantages of a thorough draft through the house pipes is considerable and keeps them much cleaner than where a trap is placed between the house and the sewer, thus disconnecting the two.

"It has been said that air coming out of soil pipes below windows of adjoining houses might cause offence. But offence could also be caused if there were a main trap and the house pipes were fouled, which they generally are not when used for ventilating the public sewers."

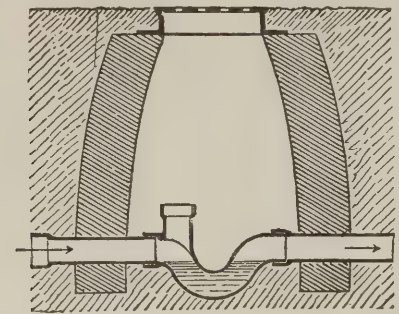

FIG. 2754.—Main Trap and Air-hole for House Drain.

There is much to be said in favor of both sides of the question, and for the present we prefer the more conservative views of Mr. Ball.

The need of draft through every part of the house drainage is not the only reason, for, as pointed out by Mr. Philbrick, it is impossible to retain the water seal in the best forms of traps, unless the atmospheric pressure is freely admitted just below the water seal. The partial vacuum that follows a charge of water as it descends a vertical line of pipe is such that without a free admission of air below every trap, the pressure on the house side of the trap would force the water through them and leave them unsealed. It becomes necessary, therefore, to apply branch vents to each separate trap, for waste pipes more than eight feet in length and less than four inches in diameter. These vents should be extended from the drain below and above the roof or at least be extended and connected to the main soil pipe above the highest fixture. Mr. Putnam and others insist that trap venting does not cure siphonage and simply favors evaporation and necessarily increases the cost of plumbing, and to overcome this fault and still prevent the danger of siphonage, he prefers the "Sanitas trap."

Down spouts from the roof should never be used as soil pipes or ventilators, for apart from the danger of frost in certain climates, during heavy rains, when generally it is most necessary to give a safe exit on account of sewer air pressure, they will be absolutely useless as ventilators and foul air may be forced into the houses.

The *house drain* receives the discharge from all waste and soil pipes and conducts it to the sewer; formerly they were made of terra-cotta in two-feet lengths and about six inches in diameter laid in cement, but owing to so many fractures caused by the settlement and weight of the walls, the insinuation of roots of trees between the joints, rat burrows, etc., the building regulations very properly require that they also shall be made of cast iron, well-jointed, the diameter depending upon the number of soil pipes and rapidity of the fall. The fall for a four-inch drain should if possible be not less than one in forty, of a six-inch drain one in sixty, and of a nine-inch drain one in ninety feet; this will insure a velocity of flow in each case of between three and four feet per second. A direct line from the house to the sewer should always be chosen; if a bend is necessary a suitable curve should be described; the place where the drain emerges from the house must be well cemented to exclude rats from the sewer. All branch drains should be made to connect with a **Y**, so that the branch current may be flowing as nearly as possible in the direction of the main current; these branches, if the plumbing is properly planned, will be necessary only for large houses. The water from the rain leaders should when practicable discharge at the head of the house drain, so that the drain may be thoroughly scoured during each rain storm. When drains discharge into a sewer liable to flooding, it is necessary to provide a tide valve between the sewer and drain, and for house drains with insufficient fall it is advisable to place an automatic flush tank at the head of the drain.

General Considerations.—It is perhaps needless to insist that sanitary plumbing involves a carefully planned system, good material and workmanship, simplicity and exposure of the work. Even the soil and drain pipes should be exposed when practicable, or at least should be accessible by panel work and covered channels in the basement. No soil pipe should be carried on the outside of the building in climates subject to frost, and to render a house safe from the contamination of sewer air it is necessary, first, that the soil pipe and all traps be ventilated; second, that the water seal in the traps be maintained and the house drain be disconnected from the sewer by the introduction of a running trap and fresh-air inlet in the manner already described, with the exceptions noted on page 765; and third, that the entire system be free from leaks or defects.

Testing of Plumbing.—Soil pipes and the general plumbing should be tested for leaks before the house is occupied. This may be done by pouring into the highest point one ounce of *oil of peppermint* in a bucket of hot water. Another person who has not come into previous contact with the oil should inspect the respective floors after a lapse of ten minutes, when the leak will be discovered by the presence of the volatile oil. The man who handles the peppermint must remain on the spot until the investigation has been made below; it requires extreme caution, as a single drop emitted elsewhere will destroy the value of the test. Special glass grenades charged with the oil of peppermint or other pungent chemicals have been prepared for use of sanitary inspectors. The system may also be tested before the water-closets are connected by soldering over the apertures where the traps are connected with the soil pipes and then filling the pipes with water. This is a severe test, but very certain, as any subsidence in the level of the water indicates a leak which can be searched for as long as the "stack" of soil pipes and drain is exposed to view.

Sometimes the "smoke test" is applied from below; the smoke, being forced up the pipes by means of a small bellows or smoke rockets, will be emitted through the leaks and thus lead to the discovery of the defects. Of course all openings known to exist must first be closed and the smoke test should be connected with the lowest possible point. This test is not so reliable as the others named. The *gas pipes* should also be tested before lathing and plastering is begun, otherwise great damage may be done. For this purpose all the outlets are capped except one, to which is attached a tube connected with an air pump and mercury gauge. Air is pumped into the whole system and the stopcock turned, and if after working the pump for some time and stopping it the gauge shows in the course of thirty minutes no signs of sinking, the pipes may be taken as in a safe condition; but if the mercury in the gauge falls, owing to the escape of air from the gas pipes, there is a leak somewhere, which may be discovered by pouring a little ether into the pipes near the gauge and recommencing pumping, while another person searches for the leak at the various joints or outlets. Very minute holes may be detected by lathering the pipes with soap and water and making use of the pipe and pump to create soap bubbles. Similar tests are applied after the gas fixtures have been connected, so as to detect the presence of defective joints and keys; in this instance every burner is turned off except one to which is attached a tube connected with the air pump and gauge.

Sewage Disposal for Villages and Isolated Houses.—When we consider the fact that over seventy per cent. of our population reside in rural districts and occupy homes without sewer connections, we see at once why wells and outhouses are often dangerous neighbors. Mr. Philbrick, of Boston, has described a system of sewage disposal by irrigation which must commend itself as safe and practicable for all small villages and isolated houses, where the land has sufficient slope to afford the requisite grade. The requisites for this system, as stated by him in Parkes' "Manual of Practical Hygiene," vol. ii., p. 484, are as follows:

"First, land adapted to grass nearly level or gently sloping at the rate of one-fourth of an acre for a single family, or an acre for a combination of eight to ten families, if provided with a constant water supply under pressure. If the water supply is limited to what may be pumped by hand one-half of the above area will be ample.

"Second, the highest part of the land devoted to this purpose should be at least five feet below the level of the top of the drain where it leaves the house.

"Third, the soil should be thoroughly under-drained, if not resting on a dry and porous subsoil by nature. Under-drains are often needed in clayey or retentive soils and should be laid at least four or five feet below the surface, at intervals of about twelve feet, with a free outfall.

"Fourth, the land should be graded, unless tolerably smooth beforehand, so as to avoid sudden inequalities. A surface that is adapted to smooth mowing by hand is good enough for this purpose.

"Fifth, the soil must be entirely free from roots of trees and shrubs. These would choke the pipes in a few weeks. . . ."

If house drainage is conducted directly into porous tiles laid under the surface, the fluid parts will escape at every joint while the solid matter is apt to cling to the interior and gradually fill them, so as to render them practically useless, hence arrangements should be made to discharge the sewage by means of properly trapped and ventilated drains into a water-tight cesspool, where it will macerate and liquefy, and to discharge the contents periodically with such a rush as to fill the whole system of distributing pipes at once and brush away slight obstructions which may have been left by former discharges. This can be accomplished by providing a stopgate in the outlet pipe where it leaves the tank to be opened by hand when the tank is full and closed again when empty, or by providing a siphon or float to discharge the tank automatically whenever filled.

Mr. Philbrick has modified Field's siphon to be used in connection with these sewage tanks. One of the objections to this plan of subsoil irrigation, while excellent in principle, is the possibility of the roots entering the porous tiles and choking them; there is also danger from frost, and if laid deeper than one foot the vegetation cannot assimilate the very matter we wish to dispose of; for these reasons the writer favors the disposal by surface irrigation along the furrows of growing vegetation or in winter on the same garden spot.

Fig. 2755 shows such a method which Mr. Philbrick says has been in use for several summers at a house used only as a summer resort, and has been attended with complete success. There is an overflow pipe from the cesspool which is perfectly tight, indicating when it is full. The gate in the outlet pipe is then opened, and the whole contents are distributed on the kitchen garden in ten minutes. If an opportunity is selected when the wind is blowing from the house to the garden, no offensive odors are perceived and the growing crops soon absorb the fluid, much to their advantage.

When a proper slope cannot be had, we must of necessity fall back upon either the earth closet, tonneau, or pail system for the collection of excreta, while the kitchen slops and refuse waters from the house should be conducted to some garden spot if practicable and disposed of by irrigation. The ordinary privy pits and open-box privies should never be tolerated; the undue prevalence of typhoid fever in rural districts is largely due to the use of these makeshifts and neglect in the disinfection of the excreta. The history of every sewered city shows a lessening of the typhoid death rate subsequent to the construction of the sewers and that the typhoid rate is always higher in sections supplied with privy pits and open receptacles. The only reasonable explanation for this is, that sewers carry away the filth and germs that otherwise would contaminate the soil and ground water. But even if there were no wells these makeshifts are still a source of danger, in so far as they favor the transmission of the infection by means of flies; nor can the possibility be ignored that the germs in leaky or overflowing boxes may reach the upper layer of the soil and with the pulverized dust gain access to the system. These conclusions were enunciated by the writer in 1895, and appear to have found ample support in the experience of the late Spanish-American war.

House Diseases.—Special reference should be made to some of the insanitary factors likely to produce disease.

Dampness of the basement and walls is certain to render the air of the house damp; this not only leads to undue abstraction of animal heat, but also influences the cutaneous functions and favors the development of micro-organisms. The air of habitations may be vitiated not only by the products of respiration and by exhalations of the skin and mouth, but also by the products of combustion, by putrid gases from decomposition of organic matter (more especially sewer air), and last, but not least, by the household dust. Dr. Charles Smart, in his able article on air and its impurities, pp. 147–155, Vol. I., has fully set forth the nature and effects of these impurities. Severe outbreaks of acute tonsillitis, marked by great inflammatory swelling of the tonsils, foul tongue, gastric derangement, severe headache, intense depression and high temperature, have been attributed by some authorities to the entrance of sewer polluted air into the habitations. Cases of typhoid fever, gastro-enteritis, diarrhœa, and dysentery have been attributed to the same cause, and Parkes tells us that in general and lying-in hospitals in which the air of wards was liable to pollution from drains, surgical fever, erysipelas, pyæmia, septicæmia, and puerperal fever were quite prevalent and fatal. Since sewers receive the excreta of patients suffering from intestinal infections and also the wash-water and secretions from persons and clothing of other infectious diseases, it may be presumed that they contain the carriers of many diseases, but it is not so easy to explain the liberation of micro-organisms from the sewage. Some believe that there is always a possibility of particles of sewage becoming dried and as particles of dust gaining access to the air, while others contend that during evaporation or from the bursting of bubbles of gas when the sewage is putrefying, the germs may be projected from the liquids into the sewer air, and may then in consequence of defective traps or joints in the drains be blown into the house. While there is ample room for speculation on the subject, in the present state of our knowledge we may conclude at least that whether sewer air contains specific organisms or not, its constant inhalation cannot fail to lower the power of the system to resist the invasion and effects of pathogenic germs, and that the emanations from choked house drains are more injurious than those from sewers. The inhalation of household dust, apart from the mechanical irritation of the mucous membranes produced thereby, may also be the means of carrying infection; since the tubercle and influenza bacillus and the pneumococcus are doubtless often conveyed from dried and pulverized sputum or mucus deposited in the room. When we recall the bad effects of deficient sunlight, of dampness, impure air, and excessive summer heat, we can appreciate why some of

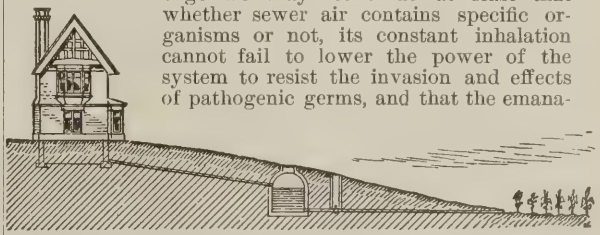

FIG. 2755.—Disposal of House Drainage by Surface Irrigation.

these factors should be especially potent in unsanitary dwellings in the production of certain typical house diseases.

Scrofula, or more correctly speaking a chronic form of tuberculosis of the glandular system, is especially common among children brought up in dark, gloomy, and damp habitations. These children are anæmic and as puny as plants reared without the stimulating effects of sunlight. Add to this fact that dampness favors the development of catarrhal conditions which render the system more vulnerable to tuberculous infection, and we have a reasonable explanation why this disease, as well as *pulmonary tuberculosis*, prevails especially among inmates of damp and dark basements and back-to-back houses. The death rate is often double and treble that of other localities, and while there are doubtless other factors which determine this frightful mortality, none are more potent than deficient sunlight and ventilation, especially in view of the fact that the ubiquitous tubercle bacillus clinging to floors and walls in carelessly expectorated sputum, may retain its vitality and even proliferate in damp and badly lighted rooms. For similar reasons *diphtheria* and *cerebro-spinal meningitis* are also more frequent in unsanitary dwellings. *Acute* and *chronic rheumatism* and *bronchial affections* are likewise of more common occurrence in damp houses, and in recently constructed houses which have not been sufficiently dried and aired. Here again the continued abstraction of animal heat lowers the vitality of the inmates and favors the development of these affections, and a bronchial catarrh thus produced may render the mucosa vulnerable to the invasion of the tubercle bacillus.

Infantile diarrhœa is more frequent and fatal among the inmates of the upper stories; this is doubtless due to the enervating effects of heat and the more speedy decomposition of food, especially the milk, in the heated atmosphere; at all events, Meinert has shown that the mortality from cholera infantum, at Dresden, was 11.27 per cent. in the top stories as compared with 9.13 on the second and 3.98 on the first floors. Similar observations have been made at Berlin, which also developed the fact that still-births occur in a larger proportion among the occupants of the upper stories of houses. Whether this condition is due to the causes already mentioned, to sociological conditions, or to stair-climbing, remains to be determined.

Sanitary Inspection of Buildings.—The eradication of preventable diseases is the highest aim of scientific medicine, and the time may come when the public is willing to compensate the physician "to prevent by watchful foresight so far as is consistent with the progress of human knowledge" the outbreak and extension of such diseases. Indeed even now it is the duty of health officers and medical officers of the public services to examine into the cause of outbreaks of contagious and infectious diseases, and it is therefore desirable to point out some of the subjects to which an intelligent sanitary inspector pays special attention. Such an examination should include the character of the site and soil, the building plans, material and construction, ventilation, heating, lighting, plumbing, water supply, and the collection and disposal of refuse, and presupposes a knowledge of the causes of propagation and best methods of prevention of infectious diseases; also a knowledge of sanitary chemistry, microscopy, and bacteriology in order to determine the impurities in air, water, soil, food, etc., the prompt and accurate diagnosis of disease and the efficient use of disinfectants;—in fact, a good sanitary inspector must possess a general knowledge of the subject under discussion, good common sense, the habit of accurately observing facts, and the power for reasoning from causes to effects and by way of exclusion.

Before beginning the examination of a building or locality proper it will be well to gather all the information possible from all persons likely to throw light on the subject of bad water, offensive odors, and many other details, for, as remarked by Mr. Frederick N. Owen, "he will often find that this testimony will be uniform in a certain direction and will save him much time and labor in the investigation he is about to make, by directing his attention to some one point as the probable cause of the trouble." There are thousands of houses, clean and well-kept inside, which are steeped in the foul exhalations rising from cesspools and vaults in the immediate vicinity; if, therefore, offensive odors are noticed only when the wind is from certain directions, the inspector would do well to look for the nuisance in that direction. The inspector should be systematic in his methods and all the observed facts should be carefully noted in a memorandum book.

1. The examination of the site should include its relations to sources of soil, water, and air pollution, such as proximity to marshes, factories, and other nuisances, the presence of ponds and stagnant pools with special reference to mosquitos as carriers of malaria. Attention should be paid to the elevation of the site and its relation to adjoining lands as regards drainage; to the amount and duration of sunlight, prevailing winds, and the character and amount of dust; and to the influence of trees close to the house in causing dampness by shutting off sunlight and air. The examination should also be directed to the cleanliness of the yards, outhouses, and the character of the diseases in the neighborhood. The writer in 1895 recorded a number of house epidemics of typhoid fever in which the infection was doubtless carried from privies to the food supply of neighboring houses by the agency of flies.

2. The examination of the soil on which the house stands, with special reference to dip of strata, porosity, and soil pollution, height and fluctuations of the ground water as determined by the water level in neighboring wells. A porous soil like sand, unless upheld by a stratum of clay, is usually dry and salubrious; clay and rock are impervious to moisture, and the water usually flows along the surface to some lower point; situations at the base of a hill are especially objectionable, as the ground water from higher levels generally comes here near the surface and renders the soil and air by capillary attraction and evaporation more moist than at any other point, and this dampness may extend to the walls of the house unless special precautions have been taken in the manner described on page 752 ("Construction of the House").

3. The examination of the plans, number of stories, construction and interior arrangement of the house should include the permeability and hygroscopic properties of the building material. Our general knowledge of the relative permeability of different kinds of building material will enable us to form an opinion, but for exact determinations the use of a poroskop, or gasometer and manometer becomes necessary. The capillary attraction may be determined by drying a suitable piece of the material, placing the lower end in water, and noting the height to which the moisture ascends. The effective humidity of certain building materials is determined by weighing a certain sample and after drying it at a temperature of 100° C. to weigh it again. The loss in weight indicates the amount of moisture. The relative capacity of certain building materials for parting with their moisture can be determined by placing two equal-sized pieces in water until completely saturated, and then, after wiping them off rapidly, exposing them to a uniform current of perfectly dry air. From the length of the time consumed in drying, the capacity for evaporating moisture may be calculated. The material, character, and condition of the roof, gutters, and rain leaders should receive careful attention.

4. The examination of the air in the interior is important. Here we should remember that whenever the volume of CO_2 amounts to seven volumes per 10,000, with a proportionate increase of organic impurities, a want of freshness is observed, and when nine or more volumes are present the organic odor becomes quite perceptible, although, as pointed out by Dr. Smart, Vol. I., p. 153, the continued occupancy of an apartment may give rise to organic odors, clinging to the walls and other surfaces, when CO_2 may not be present in large quantity. Before

entering into a systematic examination of the air for the determination of its impurities (see *Air*, pp. 147–155, Vol. I.) as regards carbonic acid, organic matter, ammonia, hydrogen sulphide, carbon monoxide, micro-organisms, and humidity, and for the determination of cubic air space for the occupants, it will be well to note the character and habits of the inmates as regards cleanliness, the amount of household dirt and dust which has accumulated on the walls, floors, and furniture, and to examine the closets, slop-pails, garbage, and ash receptacle, as well as the condition of the water-closets. The latter are often found with no connection with the outer air, being located in the middle of the house. Most of the private dwellings have no other way of changing the air than through doorways, windows, transoms, and the seams of imperfect workmanship.

5. We should study the arrangement of rooms, their length, breadth and height, floor and cubic air space for each occupant, distribution of light, number of doors, transoms and windows, sufficiency of ventilation, the size of fresh-air inlets and outlets, their cleanliness and freedom from obstruction. We should also test the humidity of the air in different stories by means of a reliable hygrometer, remembering that a humidity of 60°, saturation being 100, is the limit for healthy dwellings in this country. If the house is found to be noticeably damp, we may find the cause in imperfect cementing of cellars or basements, in the absence of damp-proof courses in the walls to prevent capillary attraction, in leaking downspouts, house drains or water-pipes, in ash heaps piled against the wall, absorbing and retaining moisture, in obstructions to air and sunlight, etc.

6. The methods of heating, as by stoves, open fireplaces, steam, hot water, or hot-air furnaces. If the house is heated by a furnace, the position of the fresh-air inlet with reference to sewer drains, underground ducts, and other impure sources should be noted. The very place which should be well cemented to exclude ground air—namely, right under the furnace—is frequently neglected. Basements and cellars must be cemented to exclude not only dampness but the equally objectionable ground air with its excess of CO_2 and other impurities. We should also note the character of fuel, the provision of dampers and presence of coal gas, the amount of heat obtained, and the quality of the air.

7. The question of natural and artificial light should receive consideration, and the average amount and duration of sunshine should be noted. Thus, for example, the proportion of window to floor space should be one-sixth or one-fifth, and in temperate climates direct sunshine should reach, when practicable, all parts of the room. The sufficiency of artificial lighting may be approximately determined by observation, and quite accurately by the employment of Bunsen's photometer. In this country, the unit adopted for the measurement and comparison of lights is a No. 6 sperm candle, burning 8 gm. per hour and giving out a light known as "one-candle-power." Such a candle, according to Munson, contains, on analysis, carbon 80 per cent., hydrogen 13 per cent., oxygen 6 per cent. The quality of the air and the temperature of the room lighted with ordinary illuminants should also receive attention.

8. The inspection of the plumbing is one of the most important features of a sanitary inspection. If an offensive odor is perceived in the basement it will suggest the possibility of a leaking drain pipe; and if inquiry reveals the frequent presence of rats, we may infer that the house drain is in direct communication with the sewer and that the traps and lead bends are likely to be gnawed and leaky. Unfortunately, in most buildings the pipes are hidden behind woodwork and underneath floors, and the owner never appreciates the importance of exposed work until the workmen have to tear up floors and walls to permit of the necessary inspection and repairs. Of course this should not be done until a general examination and the tests for plumbing already referred to indicate defective work. Very often, too, the owner has not the faintest idea of the location of the house drains and soil pipes, and this suggests the necessity of a law compelling every householder to preserve a set of drawings, showing the location of drains and vertical soil pipes.

The inspection of plumbing should begin with the main drain and proceed upward to all the ramifications, special attention being paid to imperfect caulking of joints, open connections, putty joints, holes plugged with corks, rag-patches, spots of corrosion, lead pipes gnawed open by rats, etc.

The fixtures should be carefully examined and their traps or water seals tested in order to learn their efficiency against the entrance of sewer air; this unsealing, unless special precautions have been taken, is sure to occur if the fixtures remain unused for a certain time and the water in the traps has evaporated. To make this test Mr. Owen suggests that "all the basins, baths, and other fixtures above the traps to be tested and on the same line of piping should be filled with water and then discharged simultaneously, care being taken that all the pipes are free from obstruction. The fixtures below the trap should then be filled and discharged in the same way. If the trap retain its seal under these tests, it is safe to assume that it is an effectual barrier to the entrance of sewer air." For the detection of pin holes in the pipes, etc., which cannot be seen by the naked eye, the "peppermint," "smoke test," or some other pungent chemicals should be employed in the manner described on page 766.

The following list of defects in plumbing and drainage have been encountered by Mr. Owen, and numerous specimens illustrating these defects have been observed by the writer in the Museum of Hygiene, in the City of Washington:

1. Earthen-pipe drains, either broken or with leaky joints, laid under the cellar floor, saturating earth with sewage. 2. Section of earthen pipe drains completely obstructed by the insinuation and growth of the roots of trees. 3. Pipe drains without sufficient grade or with the fall in the wrong direction. 4. Drains without running traps admitting sewer air from sewer or cesspools to the pipes in the house. 5. Drains without a free current of air. 6. Rat burrows from sewers and along drains undermining floors and admitting foul air to the house. 7. Section of soil pipe, the lumen of which was completely obstructed by urinary deposits, because of the exposure of the soil pipe on the outside walls of the house in cold climates. 8. Soil or waste pipes without any or sufficient ventilation. Defective connections between fixtures and waste pipes. 9. Lead pipes and traps gnawed by rats. 10. Water-closets, cistern with overflow joined to soil pipe or drain. 11. Safes under closets or basins connected to soil pipe or drain. 12. Two or more fixtures with unventilated traps on the same line of pipe, siphoning each other when used. 13. Sink overflow pipes joined to soil pipes untrapped or with trap liable to siphon. 14. Overflows from fixtures connected with waste pipe on sewer side of trap admitting foul gases to rooms. 15. Faulty traps and fixtures without traps. 16. Water supplies to sinks taken from water-closet or other contaminated tanks and used for drinking purposes. 17. Rain leaders used as soil pipes or ventilators to drains, delivering foul air to bedroom windows or under eaves or roofs. 18. Ash pits near larders and pantries, or liable to soak moisture to walls. 19. Defects of drainage and rat burrows from neighboring houses, especially from those located on a higher level. 20. Cesspools near houses, wells, or cisterns, polluting the drinking-water.

If an outbreak of contagious or infectious disease is being studied, and up to this point the inspector has not reached any conclusion, it is desirable to consider the possibility of the germs being carried by flies, mosquitos, and other insects. Our investigation should, of course, extend to the water supply, milk, food, and even the ice supply.

The general principles set forth in the foregoing pages are equally applicable to the inspection of public buildings, schools, hospitals, prisons, barracks, asylums, etc. (For inspection of dairies, etc., see *Milk-Borne Diseases*.)

George M. Kober.

HOWARD SPRINGS, LAKE COUNTY, CALIFORNIA.—

Post-Office.—Putah. Hotel and cottages.

Access.—From San Francisco, Sacramento, or Woodland to Calistoga, thence by stage. These springs are fourteen in number and are picturesquely located in a mountainous pine region 2,240 feet above the level of the sea. Following is a quantitative analysis of the principal springs by Prof. W. T. Wenzell, California College of Pharmacy:

One United States Gallon Contains:

Solids.	No. 1—Excelsior. Grains.	No. 2—Twin Springs. Grains.	No. 3—Eureka. Grains.	No. 4—Neptune. Grains.	No. 5—Soda. Grains.
Sodium chloride	101.67	30.96	35.70	29.61	9.38
Potassium chloride	1.13	19.71	25.65	14.64	12.81
Lithium chloride	8.35	.03	.09	.06	
Sodium bicarbonate	34.10	73.97	82.35	......	37.72
Magnesium bicarbonate	2.81	114.10	110.25	73.34	59.32
Calcium bicarbonate	6.30	10.88	5.84	32.14	35.62
Iron bicarbonate	1.85	1.14			
Alumina	.03	.15	.10	.19	.13
Oxide of iron	......	......	4.95	.20	.09
Silica	34.10	9.24	3.40	8.34	6.95
Organic matter	.14	.32	.20	.25	.26
Total	190.48	260.50	268.53	158.77	152.28
	Cu. in.	Cu. in.	Cu. in.	Cu. in.	Cu. in.
Free carbonic acid gas	134.00	77.50	150.00	120.00	117.00
Temperature of water	75° F.	102° F.	110° F.	85° F.	60° F.

It will be observed that the "Excelsior" spring is quite similar to some of the Saratoga springs of New York. The percentage of sodium chloride, however, is much less than that of its Eastern namesake, the Saratoga Excelsior, while the amount of sodium bicarbonate is about twice as great. The water is mildly purgative, and on account of the considerable quantity of lithia which it contains is useful in a number of urinary complaints, especially calculus and gravel. The "Twins" No. 2, although only six feet apart, show a remarkable difference of temperature, one being cold at 50° F., the other thermal at 102° F. The water of the hot spring is a very efficient cathartic, and is used in habitual constipation, chronic dyspepsia, and in certain diseases of the liver and kidneys. On account of the large quantity of iron contained in the "Eureka" spring, No. 3, it has gained great celebrity in the treatment of anæmia, debility, etc. The "Neptune," No. 4, is also quite rich in iron, besides containing considerable quantities of magnesia, lime, and sodium. The water is tonic and mildly laxative in its action. The "Soda" spring, No. 5, being very rich in carbonic gas, forms a pleasant cooling effervescent draught, if the water be taken directly from the spring. It contains a little iron and has mild tonic properties.

James K. Crook.

HOWARD SPRINGS, LAUDERDALE COUNTY, ALABAMA.—

Post-Office.—Florence. Hotels at Florence.

The springs are located one mile and a half from the Tennessee River, and half a mile from Florence at the junction of the Memphis and Charleston, and Louisville and Nashville railroads. The river is navigable for ten months in the year. Florence has a population of 8,000 and possesses abundant hotel facilities.

The climate in this section is mild and equable and the weather is not subject to sudden changes. In 1890 it is said that the highest temperature was 89.5° F., the lowest 64° F. The average summer temperature ranges from 79° to 84°, and the nights are almost always cool, requiring light blankets. The usual winter temperature ranges from 54° to 59° during the day, and from 40° to 48° at night. The coldest weather ever known in Florence was in January, 1893, when the mercury fell to 9.5° above zero. The elevation here is about 1,100 feet above the sea level, and the surrounding country is gently undulating. The springs are three in number. No quantitative analysis has been made, but according to an old qualitative examination by Professor Tuomey, State Geologist, Spring No. 1 contains:

Hydrochloric acid.
Sulphuric acid.
Calcium carbonate.
Iron carbonate.
Sulphurous acid.
Sulphuric acid.
Alum.
Magnesia.

Another spring is said to contain ferric alum in large proportions, and has a considerable reputation in the treatment of diarrhœa and dysentery. The third spring, about 500 feet distant from No. 1, contains sulphur, and is used in skin diseases. The waters of No. 1 have an extensive reputation in the treatment of Bright's disease, diabetes, and other disorders. For various reasons these springs have been more or less neglected since the Civil War.

James K. Crook.

HUANUEO BARK. See *Cinchona.*

HUBBARD SPRINGS.—Lee County, Virginia.

Post-Office.—Jonesville.

Access.—Viâ Louisville and Nashville Railroad to Hubbard Springs station, thence a walk of two hundred yards to springs. These springs are located seven miles from Jonesville in southwest Virginia. The surrounding country is rugged and broken in character, the springs being in a charming valley at the foot of the Cumberland Mountains. The elevation is about 1,450 feet above the sea level. There are four springs located in a space of thirty feet square, and known respectively as the "White Sulphur," the "Black Sulphur," the "Chalybeate," and the "Frustom." An analysis has been made, but the results are not known at this time. The waters are stated to be much valued in rheumatism and in disorders of the liver, kidneys, and gastro-intestinal mucous membrane. No special accommodations are provided for visitors, but board and lodging may be obtained in the neighborhood.

James K. Crook.

HUDSON HOT SPRINGS.—Grant County, New Mexico.

Post-Office.—Hudson. Hotel.

Access.—Viâ Atchison, Topeka, and Santa Fé Railroad (Silver City branch to Hudson, thence by coach to springs). The location is twenty-five miles from Deming, at the junction of the Southern Pacific and Atchison railroads. At present the accommodations for guests are limited, the hotel having been destroyed by fire and not rebuilt. Plans are completed, however, for the erection of a hotel of fifty rooms with all modern conveniences, and it will no doubt be ready for occupancy before this work is printed. The location is 5,000 feet above the sea level, and is in a broad valley open on the south for many miles, and surrounded on other sides by mountains distant from ten to fifteen miles. On the east, four miles distant, flows the Mimbres River, whose valley, from one to two miles in width, is dotted with a succession of fine farms and orchards. The variations of temperature are never extreme in this region, the air being pure and dry and the rainfall light, occurring almost entirely in July and August. The flow of water from the springs has not been measured, but it is sufficient to irrigate eight acres of land. The following analysis of the Hot Springs was made by Prof. W. D. Church, chemist:

One United States Gallon Contains:

Solids.	Grains.
Silica	1.55
Oxide of iron and alumina	.50
Calcium carbonate	4.45
Magnesium carbonate	2.62
Soluble sulphates and carbonates of sodium and potassium	13.55
Sodium chloride	2.27
Total	24.94

Temperature of water, 142° F.

It is said that certain of the diseases of the blood, liver, kidneys, and stomach are much benefited by the hot-water baths conjoined with the internal administration of water of the cold spring. On account of the equable climate it is safe to visit this resort at any season of the year. *James K. Crook.*

HUNTER'S HOT SPRINGS.—Gallatin County, Montana.

Post-Office.—Springdale. Hotel and sanitarium.

Access.—Viâ Northern Pacific Railroad to Springdale, where stages connect with the springs, three miles distant, the road crossing a magnificent iron bridge on the Yellowstone River. Hunter's Springs are situated at the base of the foothills of what is known as the Crazy Range of mountains. The location is 1,000 miles west of St. Paul and 920 miles east of Portland, Ore., and has an altitude of 4,480 feet above the sea level. The surrounding scenery is of the grand and romantic character commonly found in the Rocky Mountains. The climate is dry and salubrious, and severe storms are unknown. The thermometer seldom reaches as high as 98° F. in summer or as low as zero in winter. The springs boil up from a rocky ledge in the bottom of a little valley or basin enclosed by gently undulating hills. They are twenty-seven in number and are arranged in three principal groups, varying in heat from 148° F. to 168° F., with a combined outpour of about 90,000 gallons per hour. The water is clear and sparkling and remarkably soft. At present only the waters from the upper springs are used for the baths of the sanitarium. The baths for ladies and gentlemen are in separate buildings, each fitted with a plunge, tub, and vapor baths, and heated by the hot waters. About eighty rods from the bath-house is an outdoor summer bath, about one hundred and five feet square and from four to six feet deep, supplied with water from the lower group. This is said to be the largest bath of hot mineral water in the United States. The sanitarium connected with the springs has recently been enlarged and is adequately prepared for the reception of various classes of patients. Cases of rheumatism, liver disorder, bronchial catarrh, asthma, gout, and uterine diseases have been benefited or cured by a sojourn at this resort and the use of the waters and baths. An analysis by Professor Noyes, of the Minnesota State University, resulted as follows:

One United States Gallon Contains:

Solids.	Grains.
Silica	4.52
Alumina	.07
Iron carbonate	Trace.
Calcium carbonate	.23
Magnesium carbonate	Trace.
Lithium carbonate	Trace.
Potassium carbonate	.32
Potassium iodide	Trace.
Potassium bromide	Trace.
Sodium chloride	1.44
Sodium sulphide	.85
Sodium sulphate	.61
Sodium phosphate	Trace.
Sodium biborate	Trace.
Sodium carbonate	8.79
Ammonium (free)	.02
Albuminous ammonia	Trace.
Total	16.85

James K. Crook.

HUNTER'S PULASKI ALUM SPRINGS.—Pulaski County, Virginia.

Post-Office.—Sassin. Hotel.

These springs are located eight and one-half miles north of Pulaski City, from which point they are reached by carriages and stages. The location is very pleasant and picturesque, being about 2,000 feet above the sea level, and surrounded by beautiful mountain scenery. The average summer temperature at Pulaski Springs is 71.6° F., and malarial disorders are said to be unknown. Immediately surrounding the springs are shady lawns and charming walks and drives, which, with the pure air and romantic landscapes, render the place very attractive during the summer months. Excellent fishing and hunting may be had in the vicinity. The springs are two in number. They have been analyzed by Dr. William H. Taylor, State Assayer and Chemist, with the following results:

One United States Gallon Contains:

Solids.	Grains.
Potassium sulphate	0.31
Sodium sulphate	.32
Lithium sulphate	Trace.
Calcium sulphate	.99
Magnesium sulphate	1.26
Aluminum sulphate	16.40
Iron sulphate	1.99
Manganese sulphate	Trace.
Sodium chloride	.11
Silica	3.87
Free sulphuric acid	.63
Total	25.88

The chemist states that his analysis was not complete, and that further tests would show the presence of additional mineral ingredients. The water is recommended in dyspepsia, diarrhœa, and dysentery, and locally in catarrhal states of the mucous membranes. It is used commercially. *James K. Crook.*

HYALIN.—This is the chief organic constituent of the walls of hydatid cysts, and is related chemically to chitin. The walls of the older transparent cysts are composed of pure ash-free hyalin; those of the younger cloudy cysts are albuminous and contain various salts. Hyalin has been found only in echinococcus cysts. From the older cyst walls it is obtained in water solution under high pressure.

Pure hyalin is opalescent, transparent, insoluble in cold water, alcohol, and ether, but soluble in over-heated water (150° C.). It is not soluble in acetic acid, and only slightly in cold hydrochloric and nitric acids, but dissolves completely in hot solutions of the latter two. In concentrated potassium and sodium hydroxides it is slowly and incompletely dissolved. According to Lücke its composition is as follows: C. 44.1–45.3, H. 6.5–6.7, N. 4.5–5.2, O. 43–44.7 per cent. From the water solution it is precipitated by alcohol, acetate of lead, and mercuric nitrate, but not by acetic acid and potassium ferrocyanide or mercuric chloride. By the latter reactions it is distinguished from albumin. Neither tannic acid nor chlorine water precipitates it. If the water solution is boiled with dilute sulphuric acid reducing substances are formed, which with yeast yield alcohol and carbonic acid, and are strongly dextrorotatory, proving to be grape-sugar. It has been estimated that the older cyst walls yield fifty per cent. of their weight of this substance. From chitin, to which it is most closely related, hyalin is distinguished by its solubility in water at 150° C.

Aldred Scott Warthin.

HYALINE DEGENERATION.—Under this head there is classed by various writers a large number of pathological processes of widely differing origin and nature, characterized in common by the production of a clear, homogeneous, refractive material to which the name hyalin is applied. The most comprehensive use of this term is that employed by von Recklinghausen who defines hyalin as a homogeneous, refractive, albuminous body, staining well with eosin, carmine, picrocarmine, and acid fuchsin, resistant to water, alcohol, acids, and ammonia; in these respects resembling amyloid, but giving none of the specific amyloid reactions with iodine or the aniline stains. In accordance with this definition, he classes as hyaline substances epithelial colloid and keratohyalin (*epithelial hyalin*), the hyaline products of connective-tissue cells and intercellular substance (*connective-tissue or conjunctival hyalin*), hyaline products of coagulation (*blood hyalin*), hyaline inflammatory exudations on surfaces, into tissues, urinary tubules, etc. (*exudation hyalin*), and tissue necroses presenting a hyaline appearance (*hyaline necrosis*). Further, the hyalin formed in connective tissues is to be divided into two classes: that formed by a secretory process on the part of the connective-tissue cells, and that resulting from a degeneration or infiltration of the interstitial substance. Since these various substances are of different origin and are not chemically identical, as shown by their great difference in staining, the above classification, resting as it does only upon a common physical property, has not been accepted by the majority of pathologists, who class the greater part of these processes under other heads than that of hyalin, and restrict the term hyaline degeneration almost entirely to the hyaline changes occurring in connective tissue.

Hyaline Degeneration of Connective Tissue.—The group of changes occurring in connective tissue, in which the fibrous basic substance becomes structureless and homogeneous, is at the present time usually understood by pathologists when the term hyaline degeneration is used. In the earlier stages of this degeneration the connective-tissue fibrillæ become swollen and are gradually transformed into coarse, irregular hyaline strands or even into nodular masses; in other cases they may become confluent, forming uniformly homogeneous masses; or masses of hyaline substance may be formed between the fibrillæ, the latter gradually disappearing. Neither the hyaline material into which connective tissue may be transformed nor that by which it may be replaced has yet been shown to be a distinct chemical entity. In both cases the substance closely resembles amyloid, but differs from it in that it has no specific reactions with iodine and the aniline dyes. There are, however, reasons for believing that the chemical relationship of these substances is very close, inasmuch as it has been shown that the two are frequently found in combination and that under certain conditions amyloid may lose its specific reactions and become changed into hyalin. The formation of hyalin, similar to that of amyloid, in many cases partakes more of the nature of a *deposit* than a *true degeneration*.

The most characteristic staining reaction of hyalin is with acid fuchsin. This is best brought out by the methods of Van Gieson and Pianese. By means of this reaction it may be distinguished from amyloid, colloid, mucin, though its behavior with this stain is not always constant. The staining variations are, however, largely dependent upon the age and density of the hyaline substance, and the ease with which it is penetrated by the staining fluid. Recently formed hyalin stains light rose-red; old hyalin a very deep red when penetrated by the stain, but with Van Gieson's method it often stains yellowish, the acid fuchsin not having penetrated. It is very probable, however, that the hyaline changes in connective tissue are not identical, but represent a class of closely related conditions.

As in the case of amyloid, hyalin is most frequently found in the walls of blood-vessels, but differs from the former in being found in connective tissue without showing any relation to the vessels, particularly in the case of glandular stroma. Physiological hyalin occurs in large masses in ovarian corpora fibrosa, where it constitutes a normal formation in the process of obliteration of the corpus luteum. The formation of hyalin in the blood-vessels in old age is also to be regarded as of the nature of a physiological process. Under normal conditions the blood-vessels of the ovary are the first to show this change, and this organ at the menopause shows extensive hyaline change in the walls of its arterioles. A similar change is found at this time in the uterine vessels.

The pathological formation of hyalin may occur in apparently normal connective tissue, or in that altered by pathological processes, in newly formed connective tissue following inflammatory processes or that developing in tumors. Hyaline degeneration occurs most frequently in the walls of the blood-vessels, heart valves, endocardium, kidney glomeruli, lymph glands, splenic follicles, connective tissue of the thyroid, parotid, lachrymal and mammary glands, tunics of the testis, periosteum, bursæ and tendon sheaths. In the connective tissue of tumors it is of very frequent occurrence, particularly in the case of the endotheliomata of the serous glands and meninges. The reticulum of tubercles is often hyaline in character, and hyaline connective tissue is not infrequently formed about old tubercles, in old scars, granulomata, etc.

Hyaline change is rarely massive enough to be visible to the naked eye. When present to such an extent it is manifested by whitish, semitranslucent, hard and dense areas resembling scar tissue, replacing the normal structure. It is usually whiter and less translucent than amyloid. In blood-vessels showing much change the walls may be thickened, stiffened, and the lumen partially or wholly blocked. From the hard and dense character of the process hyaline degeneration is usually spoken of as sclerosis; in blood-vessels, either arterio- or phlebosclerosis.

Sclerosis of veins is not nearly so common as that of arteries, but is of quite constant occurrence in organs and tissues affected by chronic inflammatory processes. The sclerosis of arteries may be considered pathological when it occurs at an early age or to an excessive degree. The small arterioles of the splenic follicles, kidney glomeruli, brain and spinal cord, and the intima of the larger arteries are particularly subject to hyaline change. In many cases the hyaline substance is formed immediately beneath the endothelium in a manner similar to that of amyloid; in other cases there is first a proliferation of connective tissue beneath the endothelium, the new tissue gradually losing its nuclei and becoming converted into hyalin. Not infrequently the formation of hyalin takes place only in the outer coat of the vessel. The small arterioles of the splenic follicles and the kidney glomeruli are often the first vessels in the body to show sclerotic change. The extent and location of this change are, however, very variable; in some cases it may be confined to the coronary arteries, while in others the small arterioles of the central nervous system may alone be affected.

The connective tissue of fibromyomata very often undergoes hyaline change. Similar processes occur in the endothelial tumors of the brain, meninges, and serous glands. In these tumors the chief part of the growth may sometimes consist of hyaline material. When formed into cylinders or columns about the vessels the tumor is designated a cylindroma. In the mixed endothelial tumors of the serous glands hyaline material is formed after the manner of a secretion on the part of the endothelial cells lining the lymph spaces. A similar formation of hyalin at the expense of the interstitial cells occurs in the connective tissue of the conjunctiva and thyroid. In the latter the formation of hyalin in large amounts causes atrophy and compression of the glandular elements, so that not infrequently there is but little functionating gland structure left, the entire organ becoming changed into a hyaline mass in which the glandular remains are with difficulty made out. The basement membrane of Bowman's capsule and of the acini of the mammary gland, as well as that of the tubules of kidney and testis under certain conditions, becomes hyaline. Atrophy of the parenchyma usually follows this change. Hyaline glomerular scars (obliterated glomeruli) are almost constantly found in the kidneys as the result of the destruction of the glomerular parenchyma; a similar sclerosis of the areas of Langerhans in the pancreas may occur in association with advanced general arteriosclerosis.

Fibrinous exudates upon serous membranes may become organized and the newly formed connective tissue suffer hyaline change. Such hyaline formations are not infrequently seen upon the surface of the spleen, liver, pericardium (so-called soldier or milk spots), and pleura. Old pleuritic and pericardial adhesions may be entirely composed of hyaline material, all cells having disappeared. The hyaline bodies called rice bodies or corpuscula oryzoidea found in pathological conditions of the tendon sheaths and bursæ are for the greater part composed of loosened masses of organized fibrin which have undergone hyaline change. In cirrhosis of the liver and in chronic nephritis the new connective tissue frequently is hyaline in character. Old infarct scars show a like change. After complete organization of obturating thrombi, blood-vessels may become replaced by hyaline cords. Similarly in chronic obliterative appendicitis the appendix may become changed into a hyaline cylinder in which even all traces of the muscle coats may have disappeared.

In lymphatic glands large masses of hyalin are frequently found, particularly in the atrophic glands of old age, or in association with chronic inflammatory processes. Here the change seems to be more of the nature of a deposit or infiltration. Large deposits of hyalin occur also in the hæmolymph glands. Rarely, a progressive hyaline degeneration of many organs occurs—heart, vessels, serous membranes, spleen, lymph glands, intestinal wall, etc.,—involving these either simultaneously or one after the other. In these cases portions of the hyaline substance may give an amyloid reaction. From this it may be inferred that there is a form of hyaline degeneration which is closely related to amyloid.

Of the nature of hyalin practically nothing is known. The disappearance of the nuclei, the subsequent retrograde changes in the hyaline substance, and its sequestration from normal tissue stamp the process as being essentially degenerative in character. The causes of the thickening and homogeneous transformation are entirely obscure. It has been believed by some writers to be due to a coagulation of proteid material after the death of the cells, or that it is due to a local disturbance of metabolism. According to the latter theory the cells are unable to make use of the proteid material brought to them; this becomes precipitated or infiltrated into the interstitial substance. The cells are thus pushed apart, and gradually atrophy. In many cases the formation of hyalin just beneath the endothelium of the blood-vessels points, as in the case of amyloid, to a secretory action on the part of these cells in removing certain substances from the blood. In the cylindroma and also in the mixed endotheliomata of the parotid, the formation of hyalin appears to be due partly to a secretory action on the part of the tumor cells and partly to a degeneration of these cells. In the case of the lymphatic glands the appearances more often suggest a deposit than a degenerative process. While not bearing the same relation to tuberculosis, chronic suppurations, etc., that amyloid does, hyaline degeneration is most frequently associated with chronic intoxications. Syphilis, lead poisoning, alcoholism, over-eating, etc., are conditions favoring or leading directly to hyaline change in the blood-vessels. It is probable that hyaline material can be reconverted, absorbed, or removed. The corpora fibrosa of the ovary undergo contraction and decrease of size until they come to consist of a narrow line of hyalin only. Further, hyalin is very unstable, being frequently calcified, converted into myxomatous tissue, or undergoes complete disintegration. The hyalin of sclerotic vessels frequently suffers a fatty change with later formation of cholesterin. The effects of hyaline change upon the tissues are similar to those of amyloid.

Hyaline Bodies.—In this connection should be considered also the so-called hyaline bodies (fuchsinophile bodies, Russell's bodies, etc.) which are frequently found in normal tissues as well as in a great variety of pathological processes. They are globular, hyaline bodies of varying size, often occurring in mulberry-like conglomerations. They may be found both within cells and free in the stroma. With acid fuchsin they stain red, and with Weigert's fibrin-stain a deep blue. They are found particularly in glandular proliferations of the stomach mucosa, chronic inflammatory processes, lymphadenoid tissue, and in malignant tumors. They may occur in either epithelial or mesoblastic cells. Their frequent presence in malignant tumors has led them to be regarded as parasites, either blastomycetes or protozoa. They are almost constantly present in the hæmolymph glands where they undoubtedly represent products of the disintegration of red blood cells. In pernicious anæmia phagocytes filled with these bodies are found in large numbers in these glands. Many of the bodies give an iron reaction. In other cases the granules may arise from the oxyphile and basophile granules, the process partaking of the nature of a coagulation. The exact chemical nature of hyaline bodies is not known.

The hyaline bodies found in the central nervous system are more closely related to colloid and the corpora amylacea. Under certain conditions in gliomata arising from the spinal cord glistening hyaline masses are formed from degenerating glia cells. The condition is known as *degeneratio micans*. In other varieties of tumors arising from the central nervous system, hyaline masses staining red with fuchsin are frequently found. In the majority of cases they are probably obliterated blood-vessels that have become hyaline. *Aldred Scott Warthin.*

HYDRACETIN.—*Acetyl-phenyl-hydrazin,* C_6H_5, NH,-NHC_2H_3O. Hydracetin is a derivative of hydrazin in which two atoms of hydrogen are replaced by the phenyl and acetyl groups. It differs from acetanilid only by the presence of an imido group (NH). *Pyrodin* of commerce is an impure form.

Hydracetin occurs as a white, odorless, and almost tasteless, crystalline powder. It is soluble in fifty parts of cold water, more soluble in hot water, and very soluble in alcohol. Dose, from one-sixth to three-quarters of a grain. It was brought to the notice of the profession by Saltman (*Pharm. Central.*, May 16th, 1889) as an antipyretic and analgesic. It was thought to be of much service in rheumatic fever, phthisis, and typhoid fever. Its employment has not become general owing to its intense action and the frequency of toxic symptoms. It is a very decided blood poison, exerting a destructive action on the corpuscles and giving rise to hæmoglobinuria. Seven and a half grains are sufficient to kill a rabbit. It produces marked depression, coldness of the extremities, cold sweating, and enfeebled respiration and pulse. A ten-per-cent. ointment has been used for psoriasis and other skin diseases, its value being due to its reducing power, but this has also caused toxic symptoms (*Lancet*, 1890, ii., 38). *Beaumont Small.*

HYDRAMNION, HYDRAMNIOS.—The normal quantity of amniotic fluid at full term is from 400 to 1,000 c.c. An excessive accumulation of this fluid is known as hydramnion; ten to fifteen times the normal amount may be present. A slight excess is probably of frequent occurrence, and passes unnoticed, but an increase over 2 litres is very likely to give rise to symptoms. In the majority of cases the formation of the fluid is slow at first, but toward the end of pregnancy it increases at a more rapid rate. Occasionally the fluid may accumulate very rapidly, giving rise to serious symptoms from the sudden distention of the uterus (acute hydramnion). The condition is said to occur in one of every one hundred cases of pregnancy. It usually develops in the fourth to sixth month. Hydramnion in itself is not a disease, but is to be regarded as a secondary condition to many widely differing processes, both of the fœtus and the mother.

No constant pathological changes in the amnion itself have been found in this condition; fissuring of the epithelial layer, fatty degeneration of the epithelial cells, etc., have been described. Hypertrophy of the decidua and hyperplasia of the chorionic villi have also been found in cases of hydramnion, but the connection between these conditions has not been proved. Neither physiological nor chemical investigations as to the composition of the fluid, have yielded positive information as to its source.

The etiology of hydramnion is in many cases obscure. Inasmuch as the question of the origin of the normal amniotic fluid remains unsettled, we are not yet in a position to solve the more complicated problem of the manner of formation of the fluid under pathological conditions. The view most generally held at the present time that the normal fluid is the product of both fœtal and maternal structures is borne out by the fact that hydramnion is produced by or at least accompanies pathological changes in both mother and fœtus. We may therefore distinguish two classes of hydramnion, one of fœtal origin, the other of maternal.

Hydramnion of Maternal Origin.—Hydramnion due to pathological conditions of the mother is of much less frequent occurrence than that associated with diseased processes of the fœtus. It occurs particularly in anæmic, dropsical, tuberculous, leukæmic, and syphilitic women. In pneumonia, hepatic cirrhosis, failure of compensation in valvular lesions, and all other conditions leading to venous stagnation in the maternal body, hydramnion may occur. In such cases the condition is usually chronic, but acute heart failure with sudden development of ascites or general œdema may lead to an acute hydramnion. Loss of tone of the uterine wall is also said to favor the production of an excessive amount of amniotic fluid. Hydramnion is very likely to recur in successive pregnancies of the same individual.

Hydramnion of Fœtal Origin.—Hydramnion occurs frequently in connection with ascites and general œdema of the fœtus caused by cardiac and renal disease, and syphilis of the lungs and liver; less commonly in cases of obstruction of the ductus Botalli, stenosis of the umbilical vein, twisting of the cord, velamentous insertion of the cord, fœtal tumors interfering with the circulation, tumors of the placenta, placental hypertrophy, hydrocephalus, anencephalus, etc. In general, any condition raising the blood pressure in the umbilical vein and placenta may give rise to hydramnion.

Hydramnion has also been explained as being due to a persistence of the vasa propria of Jungbluth, but the presence of these vessels in the late stages of pregnancy is considered by some writers to be secondary to an increase of blood pressure in the umbilical vein. Excessive urinary secretion in fœtal diabetes and cardiac hypertrophy, increased activity of the fœtal skin, serous inflammations of the amnion, deficient absorption of the amniotic fluid, and increased activity of the chorion are other causes assigned by various authors. Both fœtus and mother may under rare conditions contribute to the formation of the increased amount of fluid. This occurs most frequently in cases of syphilis of both mother and child when both are dropsical.

A more recent theory for the explanation of hydramnion is based upon the hypothesis that there is in the fœtal blood a substance which causes an increased passage of fluid from the maternal vessels to those of the chorion, so that the fœtus becomes plethoric. As a result of the plethora the heart's action is increased, and this in turn leads to increased urinary secretion. The lymph-forming substance, being excreted in the urine, passes into the amniotic fluid. When the latter is swallowed by the fœtus the substance is again absorbed into the fœtal blood and a vicious circle is thus set up. This hypothetical substance in the end produces toxic effects upon the liver and kidneys leading to fœtal dropsy.

Hydramnion is not infrequently associated with unioval twin pregnancy, in that in the case of one fœtus there is a normal or lessened amount of amniotic fluid while in the case of the other there is hydramnion and hypertrophy of the fœtal organs. This has been explained in various ways, but none of the theories presented is adequate. According to Küstner one of the twins receives more abundant nourishment than the other, and this over-nutrition leads to increased heart action and resulting cardiac hypertrophy. Increased urinary secretion into the amniotic sac consequently follows and causes an increase in the amniotic fluid. Ultimately insufficiency of the heart occurs with venous stasis and liver cirrhosis, both of which factors add to the hydramnion already existing. According to Schatz one fœtus transfuses more blood into the circulation of its twin than the latter gives back to it, whereby the heart of the latter becomes hypertrophic and increased urinary secretion follows. Against both of these theories may be raised the objection that in the circulation of the twins a condition of equilibrium must ultimately be reached so that in one case blood must transfuse from the circulation of the stronger to that of the weaker; and in the other, as soon as the hypertrophic heart becomes insufficient, the normal heart of the weaker fœtus must act relatively with much greater strength than the insufficient hypertrophic one. In the case of twins arising from two ova either one or both sacs may become hydramniotic.

SYMPTOMS.—In acute hydramnion the sudden distention of the uterus causes intense pain, and there are extreme dyspnœa, cyanosis, frequent and severe vomiting and fever. In chronic hydramnion the symptoms are very much like those of cystic ovarian tumors. As the uterus becomes more and more distended it may give rise to pressure symptoms, dyspnœa, pain in the sides, œdema of legs and genitals, varices, etc. In cases of very gradual development the uterus may attain a very large size without causing much discomfort.

PROGNOSIS.—The pressure symptoms may be so severe as to endanger life, but inasmuch as the process may be controlled by the production of abortion the prognosis, in so far as the mother is concerned, is a favorable one. In the majority of cases the fœtus is either under-developed or malformed, only about one-third of the children surviving. Hydramnion of moderate degree may produce no symptoms and does not endanger either fœtus or mother.

TREATMENT.—Against the formation of hydramnion there are no therapeutic measures of avail. When the fluid accumulates in such large quantity or so rapidly as to produce serious symptoms, relief by evacuation is indicated. This is accomplished by rupturing or puncturing the membranes and allowing the amniotic fluid to escape. Premature labor usually follows this procedure and the fœtus, in case it has not reached a viable age, is lost. In the mild cases no treatment is necessary, but it is to be remembered that in such cases abnormal presentations of the fœtus are of frequent occurrence.

Aldred Scott Warthin.

HYDRANGEA.—"Seven Barks." The dried root of *Hydrangea arborescens* L. (fam. *Saxifragaceæ*). This is a medium-sized shrub with softish stems, opposite, glabrous, ovate, serrate, bright green leaves, and flattish cymes of greenish flowers. It is a native of the middle, and especially of the southern United States. The root is very much and crookedly branched, from a knotty crown an inch or two in diameter, and is usually cut into pieces from one to several inches in length before marketing. The largest of these roots are usually of about the thickness of the little finger. The color is a very pale grayish-yellow, with rusty yellow patches and streaks, but the bark has a great tendency to peel off, leaving the nearly white, very smooth wood exposed. The wood is light, tough, and splintery, and is tasteless and inactive. The bark is first sweetish and feebly aromatic, then slightly acrid.

It contains starch, a little resin, saponin, and a crystalline glucoside (hydrangin, $\frac{1}{10}$ per cent.). It has had some employment in urinary disorders, especially those accompanying "gravelly deposits," and is mildly diuretic. Dose from 2 to 4 gm. (gr. xxx. ad ʒ i.).

Henry H. Rusby.

HYDRASTIS.—GOLDEN SEAL. "The rhizome and roots of *Hydrastis canadensis* Linné (natural order, *Ranunculaceæ*)." (U. S. P.).

The *Hydrastis canadensis* is a small herbaceous perennial plant with an erect, simple, pubescent stem, from six inches to one foot in height. There are usually but two leaves, one at the top of the stem, the other attached a short distance below. The leaves are pubescent, roundish, generally five-lobed. The flower is solitary and rises from the base of the upper leaf. It is whitish or purplish and consists of a colored calyx which falls very shortly after the flower expands. The fruit is a globose, compound berry, somewhat resembling a raspberry. The rhizome is of oblique growth, 2.5 to near 5 cm. (1 to nearly 2 in.) long, and 0.5 to 1 cm. ($\frac{1}{5}$ to $\frac{2}{5}$ in.) thick, cylindraceous, usually with a few short branches longitudinally wrinkled, but plump, somewhat annulate, externally brownish-gray, often with a yellow tinge or yellowish patches; fracture short and sharp, waxy, golden-yellow or bright reddish-yellow, with a thickish bark, about ten short and narrow wood wedges and broad medullary rays; roots, if present, rather coarse, brittle, with a thick bark and somewhat quadrangular wood; odor slight, characteristic; taste very bitter, but not disagreeable, producing a somewhat astringent effect.

The plant is indigenous to North America and grows abundantly in the north and west of the United States and Canada. Only one other species of hydrastis is known, *H. Jezœnsis* Sieb., which is found in Japan.

The therapeutic properties of hydrastis depend upon the active principle *hydrastine*, which is separated in white crystals, without odor or taste, and insoluble in water. With acids it forms salts which are freely soluble in water. Much trouble has arisen from the confusing of this name with *hydrastin*, an "eclectic" extract, which is made up of the various alkaloids and resin, and is many times weaker. It is a yellowish powder. *Hydrastinine* is an artificial alkaloid formed by the oxidation of hydrastine, which breaks up into hydrastinine and opianic acid. The hydrochlorate is official in the United States Pharmacopœia, and occurs as light yellow, amorphous granules, or as a pale yellow, crystalline powder, odorless, but with a bitter, saline taste. It deliquesces upon exposure and is very soluble. *Berberine* is also present and the tonic properties of the plant are, in a manner, due to its action.

Hydrastis exercises, both locally and after absorption, an action upon the system which is beneficial in all states of congestion and hyperæmia. The results of physiological experiments with hydrastine show that it increases the activity of the nerve centres. Both the sensory and motor functions are stimulated and reflex action becomes very marked. The tone of all muscular tissues is particularly raised, the striped, unstriped, and cardiac cells being influenced, as a result of which effect there is produced an acceleration of the heart's action and of the circulation throughout all tissues. A like effect is manifested upon the uterine tissue, and this effect, if the uterus is in the pregnant state, may prove sufficient to cause abortion. There is also produced an increased activity in all the secreting organs, the flow of saliva, bile and other intestinal secretions being greatly augmented. The urine is also increased, and the alkaloid may be detected in the urine within twenty-five minutes of its hypodermic injection.

In excessive doses the action of the drug somewhat resembles that of strychnine. There are excessive motor activity with cardiac distress, and convulsions which may prove fatal. In the latter event death results from extreme depression followed by respiratory failure. In a case reported[1] two doses of twenty drops of the liquid extract produced most alarming cardiac distress in a case of bronchitis with copious expectoration. The lethal dose is given by Cerna as 0.5 gm. for each kilogram of body weight.[2] Phillips and Pembrey[3] during experimental work upon animals found that death followed 15.4 grains when given to a full-grown cat.

The action exerted upon the blood-vessels has led to its employment as an hæmostatic. Attention was directed to its use for this purpose, in Germany, in 1883, by Dr. Schatz, at a meeting of the Association of Physicians and Naturalists. He reported decidedly in its favor for the treatment of chronic hyperæmia and chronic inflammation of the internal genital organs attended by losses of blood. Since that time it has been extensively employed with very general satisfaction. In menorrhagia and metrorrhagia without organic disease, as in the various forms of metritis and endometritis, it is said to check the flow more rapidly than any other remedy. In the hemorrhages occurring at the climacteric, and the excessive menstruation of young girls in which the tissues are relaxed and congested, it has proved itself particularly useful. It also relieves all conditions of congestion of the pelvic organs, ovarian pains, dysmenorrhœa, and other distressing symptoms arising from this cause. Its effect when the hemorrhage is due to myomata appears to be uncertain, some observers claiming for it decided curative properties, while others have failed to derive any benefit from its employment. It should be administered with care during pregnancy on account of its tendency to provoke abortion, although many claim to have used it without any ill effect. One of the earliest applications of hydrastis was as a cardiac tonic, and its effect upon the heart makes its action very similar to that of digitalis. It is not equal to the older drug, but has been found very serviceable when a change from digitalis is necessary.

As a local remedy hydrastis exerts a marked action upon mucous membranes whenever altered by local congestion. It is astringent and tonic, lessening the congestion, and promoting a freer and better circulation in the part. It is employed in all catarrhal conditions of the vagina, urethra, rectum, nose and pharynx, in their subacute or chronic stages. It also exercises the same local effect upon the mucous membrane of the stomach and bowels when administered internally, and has proved of benefit in all catarrhal conditions of these organs, its local action being assisted by the increased secretions of the liver and other intestinal secretions. In hemorrhoids it is thought to act with much advantage.

The fluid extract is the preparation looked upon with most favor for local use. When diluted with water it makes an undesirable-looking mixture, but it offers the advantage of depositing the insoluble resinous material directly upon the mucous surface, which is considered most necessary if its full effect is to be secured. The strength of the solution should be from ten minims to two drachms to the ounce. For rectal and vaginal use it may be applied in the form of suppositories. For internal use the dose is from one-half to one fluidrachm.

Hydrastine has been used as a wash, in the strength of two to five grains to the ounce, as a substitute for the extract, but has not proved as serviceable. For internal use it is to be preferred, as it possesses the hæmostatic and tonic action of the drug, and is of a more definite strength. The dose is from one-eighth to one-half grain, and may be given in all conditions in which hydrastis is indicated.

The eclectic remedy, hydrastin, has been employed for many years as a stomachic, tonic, and antiperiodic, but is never used for any hæmostatic action.

Hydrastinine hydrochlorate is probably the most desirable preparation for internal administration. It acts rapidly, and reports indicate that its action is more trustworthy than is that of hydrastine or the fluid extract. The dose is from one-half of a grain to one grain and a half, every three to six hours. It may also be given hypodermically in a ten-per-cent. solution in distilled water.

Beaumont Small.

[1] British Medical Journal, report No. 258, September 8th, 1899.
[2] The Therapeutic Gazette, May, 1891.
[3] British Medical Journal, October 8th, 1901.

HYDRIODIC ACID.—Hydriodic acid (HI) is a gaseous body, freely soluble in water. The aqueous solution, however, is very unstable, constantly tending to disengage free iodine. Accordingly the United States Pharmacopœia makes official *Syrupus Acidi Hydriodici*, Syrup of Hydriodic Acid, wherein the acid is preserved from change by the presence of sugar. The syrup is clear and colorless, or slightly straw-colored, and contains one per cent., by weight, of absolute hydriodic acid. It has a sweet, acidulous taste.

Syrup of hydriodic acid has similar general properties to the other diluted sour mineral acids (see *Sulphuric Acid*), but its special employment in medicine is, because of the iodine of its composition, as a substitute for the alkaline iodides. It seems beyond question to possess the general medicinal properties of the iodides, and may be given in doses of from one-half to one teaspoonful, well diluted, several times daily. *Edward Curtis.*

HYDROA VACCINIFORME.—This affection was first described by Bazin in 1855, but for a long time thereafter was generally lost sight of. In 1888 Hutchinson described what is undoubtedly the same affection, under the title "summer eruption." A year later, Handford published in the *Illustrated Medical News* a series of cases which he proved were identical in nature with both Hutchinson's summer eruption and Bazin's hydroa vacciniforme. Since then numerous cases have been reported by English, German, and American writers, and it has been shown that the disease, although rare, is not so uncommon as had been supposed. In France, strangely enough, the affection escaped recognition after Bazin's original description, but of late it has been again described by Brocq and others.

The affection usually begins in the first years of life and has been found to be much more frequent in the male sex. The parts of the body chiefly affected are those that are unprotected and exposed to the rays of the sun, although in a number of instances it has been seen on other parts as well. The bridge of the nose, the cheeks, and the ears are most prominently affected, and next in order come the backs of the hands. Other parts of the body, if exposed to the sun, will be equally affected, as in one instance in which it appeared on the legs of a boy who went about with trousers rolled up. In a case seen by the writer, however, no lesions ever appeared on the lower extremities, although the child went barefoot during the summer. The affection comes in attacks, usually in the summer season and on exposure to the sun, although this cannot be laid down as an absolute rule, as in some instances there have been quite numerous attacks in winter. There is no itching, as a rule, yet in one of the writer's cases it was marked.

At the outset of an attack there may be slight constitutional disturbance. The first appearances are either vesicles or small red papules which rapidly become transformed into vesicles and bullæ of varying size and which often become confluent. A marked feature, which has given the affection a part of its title, is the umbilication that occurs in many of the lesions, so that a vaccination vesicle is closely simulated. The depressed centre is usually surrounded by a ring of fluid, while there is a red areola at the periphery. The centre is dark blue or black, due to the hemorrhagic and necrotic condition of the corium, which is seen through the overlying vesicle. The lesions frequently become purulent. As a rule the attacks last several weeks, but may be much prolonged by exacerbations. The centre of the lesions dries into a thick, black crust, extremely adherent, and which finally on dropping off leaves a distinct pit. In many of the cases the scarring is quite severe, and reminds one forcibly of that left by a severe variola. The tip of the nose and the edges of the outer ear are in some cases much deformed. The attacks become milder and less frequent toward puberty and usually cease by the time adult life is reached.

Histologically, according to the writer's examination, which has since been essentially confirmed by Mibelli, the small primary vesicle is shown to have its seat in the middle layers of the rete Malpighii. The upper portion of the rete is somewhat reticulated, but the fluid divides the middle from the upper layers so that a large chamber without network is produced. In the fully developed lesion, with dark umbilicated centre, there is found a necrosis of the central portion of the nodule. The outer horny layer is unbroken and stains well, while the lower horny layers have become necrotic. The middle and lower layers of the rete are converted into a reticular tissue, forming a network filled with granular detritus and leucocytes, and this network has become necrotic. This necrosis extends downward through the entire corium, ceasing just above the subcutaneous tissue. The corium has a distinctly abnormal appearance, the connective-tissue cells having lost in great part their capacity for receiving stains. The connective-tissue fibres are broken up and forced apart and contain in their interstices deeply staining granules and detritus. In the papillary layer are large necrotic blood-vessels filled with blood cells, together with some free hemorrhage into the tissue. The necrosis ceases abruptly at the sides and base of the lesion. There is some increase in thickness of the epidermis adjacent to the necrotic portion.

From these appearances it is seen that the disease begins with an inflammation in the rete and upper portion of the corium in a circumscribed area, and quickly produces a vesicle in the rete. Immediately after this a necrosis sets in, which affects the epidermis and almost the entire corium. The dilated and necrotic blood-vessels can be seen through the transparent vesicular covering, and give rise to the dark red hemorrhagic centre seen clinically.

The cause of this peculiar dermatosis is unknown. The most plausible theory is that of a vaso-motor neurosis, which in certain individuals causes, when they are exposed to the sun's rays, a circumscribed inflammation followed by necrosis.

White has described several instances which probably belong in this group, which presented some unusual features, so that it seems probable that the classical description ought to be enlarged somewhat. The exceptional features in these cases were the cessation of all activity during the warm months for ten consecutive years in one case, the continuance of the attacks throughout the whole year in another, together with failure to be influenced by exposure to sun or weather, and an extensive distribution of lesions covering a large portion of the body, instead of a limitation to the portions exposed to the influence of the sun. The lesions in these cases were also very large, and the scars left very prominent and disfiguring.

Dr. McCall Anderson has recently (1898) published two cases of this disease in brothers, in which the urine contained hæmatoporphyrin. In the other cases in which this symptom has been looked for it has not existed.

It is very difficult to classify hydroa vacciniforme, although there are several affections which seem to be somewhat related to it. Boeck's acne necrotica has numerous points in common with the affection we are considering, such as the circumscribed necrosis, the umbilication, and the enlargement of the blood-vessels with hemorrhage. The histological appearances in a case reported by Touton were also similar. It is still a matter of discussion whether acne necrotica and acne varioliformis are the same disease, so that the relationship of hydroa vacciniforme and acne varioliformis is also indicated. We have also a peculiar congenital bullous dermatitis, first described by Hallopeau and characterized often by the persistence of scars and epidermic cysts, which offers some analogy to hydroa vacciniforme, chiefly in the repeated occurrence of bullæ followed by scars and the fact that a favorite but by no means exclusive seat is the head and the backs of the hands. It may also sometimes be excited by the action of the sun.

It is possible that the chemical rays of the sun may play some part in this affection as they have been supposed to do in eczema solare, etc. Hutchinson has described cases of recurrent papular, pruriginous, and eczematous eruptions occurring chiefly on the exposed parts of the body during the summer months. Hence we have evidence that the sun's rays may cause not only superficial inflammatory cutaneous changes, but deep sharply bounded necroses.

TREATMENT.—The importance of prophylaxis is apparent—to guard the patient from the sun's rays, or from wind and storm. Protecting and soothing applications are indicated when the eruption is active. Veils of red and turmeric, which are supposed to neutralize the chemical rays, have been recommended by Unna in eczema solare and may be employed in this affection. Crocker recommends the trial of arsenic, quinine, and belladonna internally. *John T. Bowen.*

HYDROBROMIC ACID.—Hydrobromic acid, HBr, is a gaseous body which, in ten-per-cent. aqueous solution, constitutes the preparation official in the United States

Pharmacopœia under the title *Acidum Hydrobromicum Dilutum*, Diluted Hydrobromic Acid. This preparation is "a clear, colorless liquid, odorless, and having a strongly acid taste. Specific gravity about 1.077 at 15° C. (59° F.). Miscible, in all proportions, with water and alcohol. By heat it is completely volatilized "(U. S. P.).

Diluted hydrobromic acid ranks among the sour mineral acids, and is perfectly competent to fulfil the purposes described under diluted sulphuric acid. Its special application in medicine, however, is not the utilization of its sour qualities, but its employment on the one hand as a *bromide*, in substitution for the alkaline bromide salts, and on the other as a vehicle for quinine, claimed to lessen the disagreeable by-effects of the alkaloid, while not interfering with the medicinal activities of the same. As a bromide-bearing medicine, the diluted hydrobromic acid has proved itself efficient if given in adequate dose, and to have less tendency than the bromides to produce acne and the other symptoms of bromism. In using the acid for its bromine influence, its comparatively feeble strength must be borne in mind, and the dose made to correspond, in proportion of bromine represented, to the average dose of the alkaline bromides. This correspondence is no less than about seven to one, so that it takes nearly seven parts of the pharmacopœial acid to equal, in bromine strength, one part of potassium bromide. To get, therefore, the bromine effect of the moderate daily allowance of 4 gm. (ʒ i.) of potassium bromide, from six to seven teaspoonfuls of the acid would require to be given. Such doses, however, are liable to irritate the stomach, and accordingly the medicine is used most commonly in association with some bromide salt, in cases in which a full bromine effect is wanted. The acid should be diluted, for administration, ten- or twelve-fold, and the mouth well rinsed after each dose. *Edward Curtis.*

HYDROCELE. See *Testes, etc.*

HYDROCEPHALUS, CHRONIC.—(Synonyms: Internal hydrocephalus; congenital hydrocephalus; hydrops ventriculorum cerebri.)

DEFINITION.—An affection which may be defined as an abnormal accumulation of serous fluid within the cerebral ventricles, tending gradually to increase in amount, and to give rise to undue pressure on the cranial contents; in infancy and early childhood leading also to gradual enlargement of the head with separation of the cranial bones.

The term *external* hydrocephalus is sometimes employed to denote an abnormal accumulation of fluid in the subarachnoid space. It is a condition only rarely met with, and either is secondary to cerebral hemorrhage or pachymeningitis, or is associated with a congenital atrophy or defect of the brain. The effusion in this case is of a passive character, and does not give rise to pressure symptoms.

ETIOLOGY.—In the great majority of cases hydrocephalus makes its appearance in early infancy; sometimes, however, it is congenital, and the enlarged head presents a serious obstacle to the birth of the infant. Out of one hundred and three cases collected by Ruffer, in nine the enlargement was present at birth, and in ninety-three it began before the patient was six months old. As this list does not include infants born dead or destroyed during labor to save the mother, it is not to be regarded as representing the absolute relative frequency of the two classes of cases.

Instances occasionally occur in which an abnormal accumulation of fluid in the ventricles makes its appearance in adult age. These cases, however, form but an insignificant percentage, and in them there is seldom any enlargement of the cranium or separation of its sutures.

Many explanations have been offered for the presence of fluid in such abnormally increased amount in the ventricles, but we are still much in the dark and for the present it is better to regard hydrocephalus as a mere symptom associated with, or consequent upon, certain diseased conditions rather than as a distinct disease.

It has been likened to ascites, an affection in which we meet with either a direct obstruction to the venous return of the blood or a chronic inflammation of the peritoneum, and in confirmation of this theory we were told that in some cases the fluid which distends the ventricles is clear, resembling transudation fluid found in other serous cavities, while in other cases it is turbid and contains fibrinous flakes and even pus. In the latter case the lining membrane of the ventricles will be found more or less thickened and its vessels distended. On this account Huguenin proposed to make the fluid itself the test as to whether the action was of a passive or of an inflammatory character. With increased knowledge, however, this comparison is not at present regarded as entirely satisfactory.

Many years ago Hilton advanced the theory that this affection was due to an obliteration by inflammation of the channels of communication between the fourth ventricle and the subarachnoid space interfering with the outflow of fluid from the ventricles of the brain, and in recent years this view has received much support. Halliburton (*Jour. Physiol.*, vol. x., p. 232) has demonstrated that normal cerebro-spinal fluid is a clear, colorless, faintly alkaline fluid with a specific gravity of about 1.005, and is to be regarded as a distinct secretion differing from the mere transudative fluids met with in other serous cavities, in the presence of a distinct copper-reducing agent, at one time thought to be sugar, but now regarded as pyrocatechin, and in the character of its proteids which he found to consist of globulin, albumose, and occasionally peptone, rarely of albumin and never of fibrinogen. More recently Vaughan Harley examined the fluid present in hydrocephalic cases and stated that in many it closely resembled cerebro-spinal fluid in its specific gravity and in its reactions. In others, however, indications of a distinctly inflammatory process were superadded, albumin was present, and the specific gravity had risen to 1.008 or 1.009.

Following out the thoughts suggested by these investigations, Drs. Barlow and Lees regard the choroid plexuses as a special apparatus for the secretion of the cerebro-spinal fluid, and in proof of their view point to the following facts: Each ventricle is provided with its own vascular plexus, those in the lateral ventricles having a double arterial supply indicating a function of special importance, and the epithelium of the ventricles, where it covers these plexuses, changes its character from columnar to one similar in structure to that of a secreting epithelium. From these plexuses a continuous secretion, they think, takes place of the bland fluid on which the delicate structures of both brain and spinal cord rest. As this secretion is constant, means must be provided for the removal of any excess, either by absorption or by drainage. Absorption through the plexuses would appear impossible, for the supply of blood in the arteries must be kept at a higher pressure than that of the ventricular fluid, else circulation would cease; and the veins are far withdrawn into the interior of the velum interpositum. To provide drainage, therefore, communication is provided from the lateral ventricles, through the third into the fourth ventricle by means of the several foramina; thence into the subarachnoid space through the foramina of Magendie and the lateral foramina, and along the lymphatic sheaths of all outgoing nerves. The small diameter of these passages insures that the outflow shall not be too rapid. The careful experiments of Key and Retzius would indicate that this is the only way of escape for fluid from the ventricles.

In what way is obliteration of these channels of communication brought about? In the opinion of these writers it is invariably the result of some inflammatory action and not infrequently of a previous attack of basic meningitis. Attacks of posterior basic meningitis, in their opinion, may occur at a very early period of infancy, and in some cases the symptoms may be of so indefinite a character as to be overlooked or forgotten.

In illustration the authors mention the following case: George A——, seen first when ten months old, with large hydrocephalic head; was an eight-months' child. When one week old had jaundice and frequent convulsions; at three weeks would not allow his head to be raised and was comfortable only when lying; at two months the head was observed to be abnormally large, and since then it has progressively increased in size. They state that in many cases of congenital hydrocephalus the post-mortem examination has revealed the presence of adhesions, evidently of inflammatory origin, blocking the channels of exit. In some of these cases constitutional vice, more especially syphilis, plays an important part. Dr. Lewis Smith referred many of his congenital cases to this cause, and a recent writer considers that the greater number of them are due to chronic inflammation of syphilitic origin.

In a small percentage of cases compression of the veins by a tumor, either in the cerebellum or in the neighborhood of the aqueduct of Sylvius, appears to play an important rôle. Drs. Barlow and Lees consider that mere compression of the veins, without blocking of the channels of exit, cannot by itself account for the accumulation. Both Gibson and Collins, however, within the past few years have reported cases in which a tumor pressing on the aqueduct of Sylvius was apparently the chief cause of the hydrocephalus.

Although an occlusion of these foramina of exit is the very frequent condition met with in hydrocephalus, a few instances have been reported in which this affection has existed, and yet the post-mortem examination, although revealing traces of what appears to have been a previous meningitis, has not shown the presence of any obstruction. No thoroughly satisfactory explanation of these cases has yet been given. Drs. Barlow and Lees advance the suggestion that owing to the previous inflammation a paretic dilatation of the basilar and its branches has taken place, leading to an augmented blood supply to the choroid plexus and, as a consequence, to a more rapid secretion of fluid than can escape through the foramina of exit.

As a very exceptional cause of hydrocephalus in the adult, we may mention the case reported by Kratz in which hemorrhage from an aneurism in the internal carotid artery closed the foramen of Magendie by causing an adhesion of the telea choroideæ to the floor of the fourth ventricle.

Morbid Anatomy.—The results of such an increasing intraventricular pressure will be modified by the amount of resistance presented by the cranial bones, and by the quantity of the fluid present. In congenital cases, and in those in which the hydrocephalus began soon after birth, the resistance offered by the sutures is slight, and great enlargement of the head may result. In these cases, the effusion may reach the amount of several pints. In the majority of instances, however, it does not exceed a pint. As a result of the pressure exerted by this fluid the cranial cavity is expanded in all directions, but the parts entering into the formation of the vault suffer most; the fontanels become prominent, the sutures are gradually opened, and the vertical plate of the frontal and the upper part of the squamous, parietal, and occipital bones are increased in size and become thin, even to the point of transparency. To the hand of the observer the head feels soft and fluctuating, and with electric light may be seen to be distinctly translucent.

The enlargement goes on slowly, but is not always continuous. Periods of quiescence may occur, during which nature may attempt to cover in the open places not only by new growth along the edges of the bones of the vault, but also by islets of new bony tissue which are occasionally found filling in the fontanels.

The bones at the base of the brain are seldom much affected. A few instances are reported in which the bones of the middle fossa have been displaced, and in extreme cases the orbital plates of the frontal bone are not infrequently depressed by the fluid, thus altering the direction and position of the eyeball.

Though the face in these cases looks small, on account of the enormous distention of the skull, Ruffer states that it will generally be found to be quite as large, if not larger than normal.

On the soft structures of the brain the effect of this pressure is disastrous, the convolutions become flattened, the sulci obliterated, and the cerebral substance owing to compression is gradually absorbed. This absorption and thinning is especially noticeable toward the vertex, where in extreme cases it may be found not more than a few lines in thickness. The lateral ventricles are enormously distended, their ependyma is thickened, and the choroid plexuses are engorged. The structures at the base of the brain suffer in general less than those of the cortex, but in advanced cases the large ganglia, the pons, and the cerebral peduncles are altered in shape and their nutrition is impaired.

A hydrocephalic cranium is always an unsymmetrical one; measurements show that one lateral half of the head is always larger than the other. Keen and Robinson have reported cases in which the hydrocephalus was partial and the distention limited to one side. In some the anterior half may be increased out of all proportion to the posterior, or vice versa, and instances are recorded in which the expansion has been limited to one or more bones.

Associated with congenital hydrocephalus it is not infrequent to meet with other vices of conformation. One of the most frequent is spina bifida. Among other deformities occasionally encountered are hare-lip, cleft palate, and the various forms of talipes.

Symptoms.—In some cases the first symptom to attract attention is the slow, gradual enlargement of the head, which may go on for some months before any indication of pressure on or irritation of the nerve ganglions makes its appearance. Bastien reported a case in which the head had gone on enlarging for eighteen months without the intervention of any other notable morbid symptom. In other cases, however, symptoms of irritation of the nerve centres are present from the very beginning and sometimes even precede the enlargement of the head. West states that in twelve out of forty-five cases, recurring convulsions were the earliest symptom; in four more the enlargement was preceded by other indications of irritation such as squinting, severe headache, and nystagmus. In a third class the affection begins with symptoms resembling cerebellar disease, and in a fourth class the symptoms are acute from the onset.

As the disease advances, however, the prominent feature in all becomes the gradually enlarging head, the fontanels, instead of closing, increase in size, the sutures open, and the head assumes more or less a spherical shape. The amount of the enlargement is indicated by two measurements: that of the maximum circumference, and that over the vertex from the centre of one auditory meatus to the centre of the other. As a guide to the amount of the enlargement the following average measurements obtained from the heads of eight healthy male infants may be taken:

	Circumference.	Over vertex. From meatus to meatus.
At birth	13½–14 in.	9 in.
At two months	15 –15½ in.	10 –10½ in.
At four months	16¼–17 in.	11 –11½ in.
At six months	17 –17¼ in.	11½–11⅞ in.
At twelve months	18 –18½ in.	12 –12½ in.
At two years	20 –20½ in.	13 –13½ in.

Owing to the enlargement of the bones of the vertex the face assumes a triangular appearance with the base at the forehead and the apex formed by the chin; the root of the nose is flattened and broadened, and the upper eyelids are stretched. The nutrition of the hair follicles suffers owing to the continuous tension of the scalp, and the hair becomes scanty, and through it can be seen the large veins ramifying over the scalp especially in the region of the temples.

While the enlargement of the head goes on, other symptoms show themselves. The general nutrition becomes defective even though the appetite may remain good and symptoms of indigestion be wanting. The development of the body is retarded, growth is stunted, and the muscular system becomes soft and poorly nourished. Efforts at walking are long delayed, and if at last the endeavor is made, the infant's gait is more than ordinarily tottering and uncertain. The increased weight of the head throws an abnormal strain on the poorly nourished muscles of the neck. In young infants the power to raise it from the pillow may be altogether lost and assistance may be required even to turn it. Older children frequently rest the head by supporting it with both hands.

Loss of control over the sphincters and complete paralysis are of rare occurrence. Sometimes at the onset of the affection a more or less spastic condition of the limbs may exist. Pain in the head is not an infrequent complaint, and judging by the moaning and crying of the child is often severe.

Clifford Allbutt regards ischæmia papillæ as an early symptom; nystagmus and strabismus are often seen in advanced cases. Blindness the result of complete atrophy is, however, infrequent. When depression of the orbital plates takes place, the direction of the eyeball is altered and more or less exophthalmos may be observed. Convulsions occur as an occasional symptom; in some instances they are limited to one side, but more frequently they are bilateral. Not uncommonly they are followed by a temporary paralysis.

As the disease progresses to its close symptoms of pressure become more manifest, drowsiness may set in, and finally coma, from which the child cannot be roused, may end the case. Hydrocephalic children, however, offer but a feeble resistance to infection, and death is more frequently due to intercurrent disease, such as pneumonia, bronchitis, intestinal catarrh, or to one of the eruptive fevers.

When the disease runs a prolonged course, all degrees of impairment of the mental powers may be met with, from slight backwardness to more or less complete idiocy. In nearly every case periods of remission are noticed. The cephalalgia seems to cease, general nutrition improves, and for the time the head ceases to enlarge. The duration of these periods varies much. Sometimes they are so prolonged that the anxious mother indulges the dream of permanent recovery. In a few instances this does appear actually to take place. The effusion remains stationary, the sutures ossify, and the fontanels close by means of additional plates of bone, while growth increases and nutrition improves in the trunk and the extremities. Such patients may live many years. Dr. Bright's patient, Cardinal, died at the age of twenty-nine. His mental faculties shortly before his death were said to be "very fair"; his memory was tolerable. He was able to read and write and was fond of society. A few cases are reported in which a spontaneous evacuation of a large quantity of watery fluid has taken place from the nose with immediate relief to the symptoms which may have become very grave. In one or two cases the relief has been permanent. In one case in which the child eventually died, a small passage conducting from the cranium to the ethmoid bone was found at the autopsy.

In *hydrocephalus of later years* the symptoms are very obscure. It would appear to be almost impossible to distinguish between it and other chronic affections of the brain. The enlargement of the head, which in the hydrocephalus of infancy makes the diagnosis comparatively easy, is in these cases absent. Among the symptoms that have been recorded are the following: vomiting, more or less persistent headache and slow pulse, numbness of the hands and feet, attacks of petit mal, strabismus, dilated and sluggish pupils, and optic neuritis. Unconsciousness sometimes supervenes suddenly and death takes place by coma. The post-mortem appearances are similar to those of the hydrocephalus of infancy, with the exception that the amount of fluid rarely exceeds eight or twelve ounces.

DURATION.—The duration of the disease is very variable. The course is sometimes a rapid one and fatal symptoms supervene in the course of a few months. Few congenital cases survive two years. Many cases in which the affection made its appearance in the later months of infancy or in early childhood live for four or six years.

PROGNOSIS.—The prognosis in this affection is necessarily very unfavorable, but if the quantity of fluid is not great and the tendency to accumulate has at no time been very active, it may happen that one of the periods of remission may be prolonged, the general nutrition may improve, and as the body grows the size of the head may become less disproportionate. Cases of permanent recovery are, however, extremely rare, and in some of them in later life symptoms of grave mental trouble develop. We should remember, however, that a few instances of complete and permanent recovery from the earlier stages of the disease have been recorded.

DIAGNOSIS.—In the absence of any enlargement of the head hydrocephalus cannot be diagnosed with certainty. On the other hand, when the head becomes distinctly enlarged, with widely separated sutures and open bulging fontanels, there can be no room for any uncertainty. When the head is only slightly enlarged and the sutures are not distinctly opened, it may be difficult to distinguish it from the enlarged head met with in rachitis. The following points may assist us: In rachitis the head is square rather than round, the vertex is flattened, the frontal eminences are prominent, but the frontal bones themselves are not bulging and the sutures are closed; there is no deviation in the direction of the eyeballs, and palpation fails to communicate any sense of fluctuation. In hypertrophy of the brain the increase is very gradual, the skull is firm and unyielding, and the enlargement is more marked at the vertex than elsewhere. Occasionally we have a thickening of the bones of the skull cap due to syphilis, but no great difficulty should be experienced in distinguishing this.

In hydrocephalus of adult life the diagnosis must always be extremely difficult. Martin Prince lays much importance upon the variation in the intensity of the symptoms from day to day in this affection as compared with their uniformity in cases of brain tumor.

TREATMENT.—In a disease such as this, in which the prognosis is so grave, it is impossible to speak with any confidence of the treatment by drugs. In congenital cases in which there is a distinct syphilitic history the administration of mercury and potassium iodide has in a few cases appeared to be of much service. Their administration should be commenced as early as possible and pushed energetically, and it is to be remembered that young children bear both of these drugs proportionately much better than do adults.

External compression of the skull by means of strips of adhesive plaster may in congenital cases produce some slight diminution in the circumference of the skull, but its employment without aspiration of some of the fluid appears to be irrational and is not free from danger. Aspiration of the lateral ventricles, if performed antiseptically and the fluid drawn off slowly with the head well depressed, is an operation which does not appear to be attended with much danger, and is one which in many cases will be followed by temporary improvement. With the infant under an anæsthetic a small trocar may be thrust downward and inward into one of the outer corners of the anterior fontanel, care being taken to avoid the longitudinal sinus. This little operation often gives good results in those cases in which the symptoms of compression are advancing rapidly, but have not existed for a long period, removing the tendency to convulsions, relieving pain, and leading to a general improvement of both bodily and mental functions. The chief dangers associated with it are the introduction of infectious material and the possibility of inducing a state of collapse, both of which may be avoided with care. After the aspiration it is well to use some compression over the vault. Ewart, of London, at the meeting of the British Medical Association (1901), advised the introduction of aseptic air into the ventricles at the same time that the fluid was drawn off. This he accomplished by the introduction of two cannulæ into the right sphenoparietal region, allowing the fluid to escape by the one, and permitting carefully filtered air to enter by the other. He claimed for this method a more complete evacuation of the ventricular fluid, and an avoidance of the danger resulting from the sudden and complete removal of pressure. In one of the cases which he reported he removed in ten separate tappings fluid amounting in all to eleven pints. At the time the report was made the condition of the child was greatly improved. Any such operation, however, rarely affords more than a temporary benefit.

Lumbar puncture, advocated in this affection some years ago by Quincke, has in a few cases appeared to be of some benefit, but it offers a hope of service only in those rare cases in which there is no blocking of the channels of exit. Considering the excellent temporary results obtained in many cases by aspiration during the past few years, efforts have been made by some surgeons to establish permanent drainage of the ventricles by establishing an artificial communication between them and the subarachnoid space. Sutherland and Cheyne report three cases in which a small opening was made in the dura, and one end of a number of strands of catgut tied together was passed into the ventricle while the other end was retained in the subdural space. The results, however, were unfortunate, although temporary improvement followed in two cases. Drs. Barlow and Lees, however, report one case treated in this way as a remarkable success.

More recently Mr. McAdam Eccles reports continuous improvement in a case on which he operated, using horse hair instead of catgut as a drain, passing one end of the strands under the dura mater and the other into the right lateral ventricle. The possibility of thus replacing the natural channels of exit from the ventricle into the cavity of the subarachnoid or even into the subcutaneous spaces appears, by the results obtained in these operations, to be feasible, and we are hopeful that with improved technique we may yet be able to do much in the way of relief for this very unfortunate class of cases.

Alexander D. Blackader.

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HYDROCHLORIC ACID.—Muriatic Acid, HCl. Under the title *Acidum Hydrochloricum*, Hydrochloric Acid, the United States Pharmacopœia recognizes "a liquid composed of 31.9 per cent., by weight, of absolute hydrochloric acid, and 68.1 per cent. of water." Such grade of acid is "a colorless, fuming liquid, of a pungent odor, and an intensely acid taste. Specific gravity: about 1.163 at 15° C. (59° F.). Miscible, in all proportions, with water and alcohol" (U. S. P.). Hydrochloric acid must be kept in glass-stoppered bottles and protected from the light.

The physiological effects and therapeutic applications of hydrochloric acid so closely resemble those of nitric acid that a separate description is unnecessary (see *Nitric Acid*). For medicinal use, proper, the following official preparation is established by the United States Pharmacopœia:

Acidum Hydrochloricum Dilutum. Diluted Hydrochloric Acid.—This preparation is a simple dilution of the strong acid of the Pharmacopœia with distilled water. It represents ten per cent. of absolute hydrochloric acid, is a colorless and very sour fluid, irritant though not corrosive, and of the specific gravity 1.050. Dose, from ten to thirty drops, largely diluted with water, and the mouth to be rinsed well after the taking of each dose.

Edward Curtis.

HYDROCOTYLE. See *Umbelliferæ.*

HYDROCYANIC ACID.—Hydrocyanic, or, as it is so commonly called, *prussic* acid (HCN), is, in pure or anhydrous condition, a thin, colorless, very volatile, very unstable, and fearfully poisonous fluid. Being so unmanageable in the concentrated state, the acid is used in medicine only in dilute solution in water or in alcohol and water. In continental Europe solutions of various strengths are to be met with, ranging from two to twenty-five per cent. What is known as *Scheele's* acid is an aqueous solution from four to five per cent. in strength. Under the title *Acidum Hydrocyanicum Dilutum*, Diluted Hydrocyanic Acid, the United States Pharmacopœia establishes "a liquid composed of two per cent., by weight, of absolute hydrocyanic acid, and ninety-eight per cent. of water." This preparation is made by distilling a mixture of potassium ferrocyanide and diluted sulphuric acid, receiving the distillate in a receiver containing water. The product is finally brought to standard strength, as determined by assay, by the addition of distilled water. Diluted hydrocyanic acid may also be prepared extemporaneously by the following process, officially authorized: "Silver cyanide, 6 gm.; hydrochloric acid, 5 c.c.; distilled water, 55 c.c. Mix the hydrochloric acid with the distilled water, add the silver cyanide, and shake the whole together in a glass-stoppered bottle. When the precipitate has subsided, pour off the clear liquid." In this process double decomposition ensues between the silver cyanide and the hydrochloric acid, with the formation of hydrocyanic acid which remains in solution, and silver chloride which precipitates.

Diluted hydrocyanic acid is "a colorless liquid, of a characteristic odor and taste, resembling those of bitter almonds. As it is very poisonous, great care should be taken in tasting it. It is completely volatilized by heat" (U. S. P.). The acid is more or less prone to decompose, thereby losing strength, and in such decomposition commonly turns dark, even getting in time to look like a thin ink. This decomposition will certainly and rapidly go on under exposure to the air in an open vessel, and is also hastened by the action of light. The preparation must, therefore, be put up in small, dark, amber-colored vials and kept in a cool place protected from the light. An important point is to have the vials *cork*-stoppered, and not *glass*-stoppered, since, for some reason, the preparation deteriorates much faster in glass-stoppered bottles than in those closed by cork. The acid will keep better, furthermore, according to Squibb, if, in dispensing, quantities be drawn from the stock bottle by a pipette instead of by pouring.

Physiologically, hydrocyanic acid is remarkable for deranging, swiftly and strongly, the functions of nerve apparatus, apparently irritating and quickly exhausting certain nerve centres, and also tending to destroy the conducting power of nerves and the contractility of muscles generally. Probably by virtue of these actions, hydrocyanic acid is a peculiarly speedy and powerful poison. (See *Hydrocyanic Acid: Toxicology.*)

The application of hydrocyanic acid in *therapeutics* does not amount to much. By reason of its poisonous nature, the medicine can be used only in insignificant doses, and the only medicinal virtues that such doses possess are to allay pain or irritability of the stomach, and, less certainly, the irritability of the air passages in disease that leads to dry cough. The local use of hydrocyanic acid solutions as lotions in skin disease, to allay pain and itching, is not without danger of inducing constitutional poisoning by absorption through unobserved abrasions.

Hydrocyanic acid in the form of the dilute solution of the United States Pharmacopœia is commonly prescribed in doses of from two to four drops only, but there certainly is no danger in doses of 0.50 gm. (♏ vij. or viij.), and such doses are used by many practitioners. Furthermore, since the effect of the drug is very evanescent, and there is no evidence of any so-called cumulative action, there is no objection, physiologically, to the repetition of even a full dose so often as every hour. The dose may be administered in water, or syrup and water, and may be combined with alkaloidal salts, but not with salts of the metals. For a skin lotion, the pharmacopœial acid is variously diluted from ten- to fifty-fold by different practitioners.

Quite recently there has been published * an account of some interesting experiments by Jacques Loeb and Warren H. Lewis in the Hull Physiological Laboratory of the University of Chicago, on the prolongation of the life of the unfertilized eggs of sea-urchins by potassium cyanide. Ordinarily such eggs, kept in sea-water at a temperature of about 20° C., lose their power of development, on fertilization, in from twenty-three to forty-eight hours, or less. But if to the sea-water be added a certain percentage of potassium cyanide (one part of an "$\frac{n}{10}$" cyanide solution to 100 parts of sea-water), the time during which the capacity for fertilization persists is very materially lengthened—from one hundred and twelve to one hundred and sixty-eight hours, according to degree of development attainable. And such prolongation obtains for parthenogenetic as well as for sexual development. The experimenters account for these results by the theory that normal death of the unfertilized eggs is due to "specific mortal processes" which "are checked or modified by the process of sexual or osmotic fertilization," and which also may be checked by potassium cyanide, "which substitutes for the destructive action of these processes a condition of suspension of life ('vie latente' of Bernard)." *Edward Curtis.*

HYDROCYANIC ACID. (TOXICOLOGICAL.)—As the various cyanic poisons—hydrocyanic acid, the cyanids, impure oil of bitter almonds, cherry-laurel water, etc.—all owe their poisonous qualities to the presence in them, or liberation from them, by the action of the liquids of the economy, of hydrocyanic acid, their action is in the main the same. The rapidity of their action depends upon the proportion of hydrocyanic acid which they contain, and is modified somewhat in kind by the nature of the substance with which the acid is combined, as in the case of potassium cyanid.

Although Dioscorides casually mentions the poisonous nature of bitter almonds, and Madden, in 1731, called attention to the toxic powers of cherry-laurel water, the toxicological history of hydrocyanic acid itself begins with the year 1803, when its poisonous nature seems to have been first recognized by Schrader. The existence of the acid had been discovered twenty years earlier (1780) by Scheele, whose death has been frequently attributed to accidental inhalation of its vapor. It would seem, however, from the account given by Crell at the time (*Annalen,* 1787, i., 192) of Scheele's last illness, that his death was due to disease and not to poison.

According to Stillé, Borda (1804) first suggested the use of the artificially prepared hydrocyanic acid as a remedy in cases in which cherry-laurel water had been previously used. A few years later (Hufeland's *Journal,* 1813, p. 113) occurred the first case, of which we have been able to find record, of death of a human subject by the action of this poison. This was the case of a child who swallowed a quantity of the dilute acid which a physician had prescribed for the mother. Within the few succeeding years deaths occurring in a similar manner, from misadventure, or by reason of the varying degree of concentration of the medicinal acid used, became very numerous, and in consequence the drug fell into disrepute.

In more recent years the extensive use of the cyanids of potassium, silver, etc., in the processes of photography, electroplating, and gilding has placed these active poisons at the easy disposal of many, has led to numerous cases of poisoning through carelessness and misadventure, and has brought potassium cyanid into prominent notice as one of the most frequently employed of poisons.

The statistics of poisoning in different countries afford somewhat contradictory information as to the degree of frequency of the use of the cyanic poisons. Tardieu gives a table of criminal poisonings in France from 1851 to 1863, including 617 cases, of which there is none by the cyanic poisons. The Reports of the Registrar-General of Great Britain for 1863–67 include 2,350 poisonings from all causes, of which 151 were caused by hydrocyanic acid and potassium cyanid, a number only exceeded in the cases of laudanum and the salts of lead. During the same period there were 6,696 suicides, of which 673 were by poison, and of these the cyanic poisons head the list with 121 cases. Of 1,263 murders 19 were by poison, and of these, 5 were by laudanum and 4 by the cyanic poisons. Lesser gives a table of 431 cases of poisoning occurring in Berlin, from 1876 to 1882, of which 74 were by potassium cyanid and 12 by hydrocyanic acid, while the only substance which caused a greater number of deaths than the former is carbonic oxid, 185. In our own country statistics of poisonings are exceedingly meagre, and such as exist are valueless by reason of insufficient and inaccurate data.

Murder by the cyanic poisons does not seem to be frequently attempted. By suicides hydrocyanic acid is often the agent selected, because, probably, of its rapid action, while the facility with which potassium cyanid can be obtained by any one is a reason of its frequent use for the same purpose. Accidental poisonings by the cyanic poisons are the result of carelessness or ignorance. A solution of potassium cyanid has been hastily drunk in mistake for water. The same substance in the solid form, bought to clean brass buttons, has been swallowed in mistake for another solid purchased at the same time. Numerous poisonings by oil of bitter almonds used for flavoring articles of food are recorded. Instances of death or serious poisoning caused by the medicinal administration of hydrocyanic acid are by no means as infrequent as they should be. In several cases the intent of the physician has been called in question, and a trial for murder or manslaughter has resulted.

EXPERIMENTS ON ANIMALS.—*Method of Action.*—As in the great majority of cases in which the human subject has succumbed to the action of the cyanic poisons, the clinical history has reached the last chapter before, or shortly after, the arrival of the physician, what knowledge we possess concerning their mode of action has been derived mainly from experimentation. Unfortunately the experimental method has, in the hands of different observers, led to widely varying opinions regarding the mode of action of these poisons.

The following is the usual train of appearances following the administration of a lethal, yet not overwhelming dose of hydrocyanic acid to a warm-blooded animal: There is dyspnœa, beginning with a few hurried respiratory movements, the animal staggers and falls in a powerful tetanic spasm, with opisthotonus, during which the diaphragm is fixed in contraction; the pupils are dilated; the tongue and eyeballs protruding, the latter glassy; there is involuntary evacuation of urine and fæces; the pulse rapidly diminishes in force and frequency, and, if the dose be large, the animal dies without any further symptoms. If the animal do not die at this point, the muscles relax; the condition of tetanus passes into one of general paralysis, with total loss of reflex irritability; respiration is resumed, the expiratory acts being quite long and the inspiratory very short, and the intervals between the movements being very long. The pulse is irregular, frequent, and barely perceptible. If the animal recover, the respiration and pulse gradually return to the normal; if it die, the intervals between the respirations increase in length, the pulse becomes imperceptible. No further convulsive movements are observed, except, immediately preceding death, a single convulsive expiratory effort attended by a piercing cry or shriek.

That hydrocyanic acid destroys life by the disorders of respiration which it produces may be regarded as certain; but concerning the underlying causes of these disorders no such certainty can at present be said to exist.

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* The American Journal of Physiology, January 1st, 1902.

Preyer, from a number of carefully conducted experiments, has concluded that hydrocyanic acid causes death by irritation of the peripheral branches of the vagus in the lungs and heart. In his experiments doses otherwise certainly lethal did not kill animals in which the vagi had been previously divided; and when animals so prepared were killed by larger doses of the poison, they did not die from suffocation, as they otherwise would have done, but from the paralyzing action of the poison upon the heart. Preyer has further shown, not only in his earlier experiments, but in others, made subsequently to the publication of Böhm's views (see below), that while rabbits and guinea-pigs were invariably killed by 0.2 c.c. of a two-per-cent. solution of hydrocyanic acid, they did not die, but recovered after more or less severe symptoms of poisoning, if the same dose was administered to them shortly after they had received hypodermatically 0.5 c.c. of a one-per-cent. solution of sulphate of atropin. Atropin having been shown to produce paralysis of the peripheral branches of the vagus, an antagonism of the two drugs is explainable on the supposition that hydrocyanic acid possesses the power of irritating those nerves.

Böhm not only does not substantiate the views of Preyer, but reaches very different conclusions, which he thus summarizes: "1. The action of hydrocyanic acid is upon the central nervous system, whose functions are destroyed by larger quantities after a short period of stimulation. 2. The disturbances of respiration and circulation have their origin in analogous modifications in the activity of their centres in the medulla oblongata. 3. The vagus plays no part whatever in the action of hydrocyanic acid upon the respiration or upon the heart. 4. Atropin is no antidote to hydrocyanic acid. The only rational method of treatment of this form of poisoning is in the early use of artificial respiration."

It may be said in support of the views of Preyer, as against those of Böhm, that, while the experiments of the former were performed upon rabbits or guinea-pigs in a condition as near the normal as possible, and free from restraint, those of the latter were conducted upon cats, confined in the dorsal position, upon which tracheotomy had been performed, the jugular vein being in communication with a cardiograph, and which had been narcotized with varying quantities of chloral. Certainly the conditions of Preyer's experiments were the more likely to afford evidence of the normal action of the poison.

Amory differs from both Böhm and Preyer. He holds that artificial respiration neither prevents poisoning by hydrocyanic acid nor materially aids its elimination, although it may prevent the occurrence of convulsions or muscular spasm; that muscular irritability and nervous conduction are not impaired by hydrocyanic acid, if artificial respiration have been maintained, until after cessation of cardiac pulsations; that death from hydrocyanic acid is due to some other cause than asphyxia, "and it may be suggested that the fundamental cause is a state of blood-poisoning, due to some alteration either of the physical or the chemical condition of the blood."

The last sentence of Amory, quoted above, expresses a view which is conceded by Preyer, Böhm, and all other observers, that whatever may be the action upon any portion of the nervous system, a distinct change in the chemical composition of the blood occurs in poisoning by hydrocyanic acid. Upon this point much light has been shed by the observations of Preyer, Hoppe-Seyler, and Gaethgens. Cl. Bernard observed that under the influence of hydrocyanic acid the venous blood becomes red. According to the observations of Gaethgens, at the moment when the convulsive seizure marks the beginning of the action of the poison the venous blood assumes a bright red color, and a similar change in color from the usual venous tint to bright red is seen in the blood of the right heart. At a later stage, however, the venous blood in the cavæ, portal vein, and the right heart assumes a darker hue than that of normal venous blood; and this dark-colored blood is found in the veins of warm-blooded animals which have died from the action of the poison, even if the autopsy be made immediately after death. Quantitative analysis of the gases absorbed and exhaled by animals under the influence of hydrocyanic acid showed that in the beginning of the poisoning, while the venous blood is bright red, less carbon dioxid is produced than normally, and at the same time the expired air is richer in oxygen than usual—conditions which are the opposite to those observed in ordinary suffocation. In the later stages the elimination of carbonic acid is increased. Gaethgens also showed that prussic acid does not destroy the power of reduced hæmoglobin of taking up oxygen from the atmosphere; that fresh blood, saturated with oxygen, does not give up any of its oxygen by the action of hydrocyanic acid; that blood containing hydrocyanic acid does not give up carbonic acid to an atmosphere free from that gas; and that the separation of oxygen from fresh blood is impeded by the presence of hydrocyanic aid.

Preyer, and also Hoppe-Seyler, have obtained, by the action of hydrocyanic acid upon oxyhæmoglobin, a crystalline product, formed without separation of oxygen, which differs materially from oxyhæmoglobin and from reduced hæmoglobin in appearance and in properties, which has not the power of ozonizing oxygen, and which is not converted into oxyhæmoglobin by exposure to atmospheric air.

It seems clear, therefore, that hydrocyanic acid has the property of preventing the proper appropriation of oxygen by the tissues, as well as the formation, or at least the elimination of carbon dioxid, by entering into chemical composition with the blood pigment. It is probable also that this property is an important factor in the action of the poison upon the animal economy, although it can hardly be stated that this is its only method of action.

SYMPTOMS.—*Inhalation.*—Owing to the ready volatility of hydrocyanic acid, its absorption by the pulmonary surfaces is rapid. Coullon observed that "the odor of the acid caused one to fall unconscious and motionless." Ittner suffered from "constriction of the chest, interference with respiration, vertigo, lassitude, and shuddering," in consequence of having inhaled the vapor. Heller mentions a case in which severe tetanic spasms were produced by smelling a bottle containing a five-per-cent. solution. Dr. Letheby was rendered unconscious by smelling a bottle containing the concentrated acid. Taylor relates the case of a lady who "was immediately seized with dizziness, stupor, inability to stand, and faintness," from inhalation of the vapors produced by spilling a quantity of the five-per-cent. solution upon her dress. A student, engaged in preparing the acid in an apparatus whose joints permitted the escape of vapor, was found, after several hours, insensible, with closed eyelids, widely dilated pupils, cold limbs, and barely perceptible pulse. The muscles of the arms and legs were firmly contracted, the patient was in a condition of profound coma, but recovered after several hours (Regnauld). Coullon records a case in which inhalation of prussic acid vapor destroyed human life—that of a chemist who died in consequence of having spilled a quantity of the acid upon his naked arm. As but little, if any, absorption could have occurred through the skin, the fatal result was probably due to inhalation of the vapor.

Industrial poisoning by inhalation of prussic-acid vapor sometimes occurs in workshops devoted to electroplating and gilding, in which, by reason of imperfect ventilation, the vapors constantly emanating from the cyanid baths are allowed to accumulate. Persons exposed for a number of hours to such an atmosphere suffer from shooting pains in the forehead, pain in the region of the heart, palpitation, difficult respiration, a sense of constriction of the throat, and fits of weakness and somnolency.

By the Stomach.—The action of hydrocyanic acid, when taken by the mouth, varies with the magnitude of the dose, the degree of concentration having little, if any, influence. When taken in quantities above the medicinal dose, but still below that capable of causing death (♏ x. to xx. of the U. S. P. acid), it causes a sense of constriction of the chest, a feeling of impending suffocation, irritation of the throat, a sense of heat in the epigastrium, dizziness, impeded locomotion, a sense of constriction and heaviness of the head, and in some cases nausea or a craving for food. Salivation and ulceration of the mouth frequently occur.

When small poisonous doses are taken, the patient, in the act of swallowing, notices the hot, bitter taste of the acid, and almost immediately a sense of constriction of the throat. In the course of one or two minutes there are severe pain and sense of pressure in the head, increasing vertigo, progressive confusion of intellect, obscuration of vision, insensibility, with loss of muscular power. The face is pale and bloated, the eyes are prominent and glassy, the mouth is marked with froth. The patient is then seized with convulsions of a tetanic character, with the jaws firmly clenched. The pulse is quick, the respiration slow and stertorous, and mucous râles are heard over the chest. Vomiting is uncommon; if it occur, it is usually the beginning of recovery. The vomited matter, as well as the breath, has the odor of bitter almonds. If the case terminate in death there are usually strong tetanic convulsions, involuntary evacuation of urine and fæces, opisthotonus; then succeeds a condition of general paralysis, and death from asphyxia follows in a period varying from two hours to two days. When recovery occurs, it does so gradually, the respiration and circulation slowly returning to the normal condition without any further complications.

With large doses subjective symptoms are entirely absent. In less than a minute consciousness is suddenly lost and the patient falls if standing or sitting. Then usually follows a short convulsive seizure, during which there is in most cases involuntary evacuation of urine and fæces. After this the patient lies perfectly still, with prominent, glassy eyes, jaws firmly clenched, mouth covered with foam, face at first bloated, afterward pale and sunken, pupils dilated and insensible, surface cold and clammy, and muscles completely relaxed. The pulse, at first somewhat more frequent than normal, rapidly becomes weaker, until in the later stages it is imperceptible. The respiration is spasmodic, the inspirations are short, and immediately followed by a protracted expiration, after which succeeds a pause of considerable duration, increasing as the case progresses to a fatal termination. Death occurs during one of these pauses, the only apparent difference between the condition of the patient before and that after death being that no succeeding inspiration occurs.

Lethal Dose.—The determination of what is the minimum lethal dose of any poison is difficult, and more difficult in the case of hydrocyanic acid than in that of any other poison. This is chiefly because of the great variation in the strength of the medicinal acid, which, even if made of the proper degree of concentration originally, deteriorates rapidly by exposure to light or air.

Two cases are recorded in which the lives of adults were destroyed by ♏ xx. of Scheele's acid (= one grain or 0.065 gm. anhydrous acid, if the preparation was of the proper strength). It is probable, therefore, that one grain of anhydrous hydrocyanic acid (= ♏ xlv. U. S. P. acid) is the minimum lethal dose. It by no means follows that this amount is necessarily fatal. In a case in which so large a dose as 2.4 grains (0.156 gm.) of anhydrous acid was taken, the patient recovered under active and immediate treatment. Records of large doses, followed by recovery, are to be regarded, however, as of little value unless the true strength of the acid has been determined. Thus, in a French case, in which an adult male took ʒ ij. of Scheele's acid in two doses, without ill effects, and subsequently ʒ ij. of Vauquelin's acid (in all 10.2 grains = 0.66 gm. of the anhydrous acid), from which he suffered the usual symptoms, but finally recovered, the former preparation probably contained little, if any, hydrocyanic acid, and the latter was much deteriorated.

Treatment.—As a rule the patient will be found well under the influence of the poison, frequently apparently lifeless; yet treatment should not be neglected, however desperate the case may seem. The clothing should be instantly removed and cold water dashed upon the head and spine, which are then to be rubbed dry with, preferably warm, towels, and the cold affusion repeated; this should be done even if the patient is in convulsions. Any poison remaining in the stomach is to be removed by the use of the siphon, the stomach being subsequently washed out with warm water. Artificial respiration is strongly recommended by some authorities, by others considered to be useless. The constant current from twenty-five cells may be applied, one pole over the apex of the heart, the other over the pneumogastric in the neck, contact being made and broken coincidently with the inspirations. Friction with hot liniment is to be applied to the chest and abdomen. Ammonia and chlorin by inhalation have been frequently recommended. When used they should be much diluted with air; the former obtained by saturating a cloth with liq. ammon. dil., the latter by moistening chlorid of lime in a wide-mouth bottle with dilute vinegar. Ammonia and chlorin do not act as chemical antidotes, but as stimulants to the capillary circulation, an effect which is best attained by the injection of ammonia into a vein. Atropin hypodermically administered is regarded by Preyer as the physiological antidote of hydrocyanic acid, but, although Preyer's experiments have shown that animals already under the influence of atropin are more or less protected from the action of hydrocyanic acid, the use of atropin in cases of poisoning by hydrocyanic acid does not seem to be of much benefit. Although a mixture of persulphate and protosulphate of iron acts as a good chemical antidote to hydrocyanic acid, by converting it into the insoluble Prussian blue, its value is much diminished by the fact that it cannot usually be administered in time to prevent the absorption of the poison. It should be administered if possible; ʒ ij. of magnesia are first given to neutralize the acidity of the contents of the stomach, and immediately afterward a mixture composed of liq. ferr. tersulphat., ʒ ij., and ferri sulph. præcip., gr. xv., dissolved in water; afterward, in a few moments, the stomach should be washed out.

Post-Mortem Appearances.—Rigor mortis usually sets in early, and persists sometimes for days, particularly in the lower jaw. As in sudden death from any cause, putrefaction is rather more rapid than usual. The face is usually placid, sometimes bloated; the eyes are prominent and glassy, the pupils dilated; the mouth is more or less covered with foam. The veins everywhere are distended with dark, fluid blood. The brain tissue is normal, the cerebral vessels are full of dark, fluid blood. The left ventricle of the heart is usually firmly contracted and empty, the right heart full of dark, uncoagulated blood. But if death occur very rapidly, the blood may be bright red in color (see above). The larynx and trachea are filled with a bloody foam, and the lungs are highly congested. The stomach frequently presents no abnormal appearance, but usually it is red and inflamed, either over its entire extent or in patches. The most distinctive character noticeable is the odor of bitter almonds. This, in some cases, may be distinguished before any incision is made, sometimes only on opening the cranial cavity, the stomach, or the pericardium; while in some cases of undoubted poisoning by hydrocyanic acid the odor cannot be detected with certainty.

Detection after Death.—Owing to the great volatility and instability of hydrocyanic acid, the probability of its detection by analysis in the cadaver diminishes rapidly as time elapses, particularly if the conditions favoring putrefaction obtain. The analysis, therefore, if one be desirable, should be made as soon as may be after death. Nevertheless, instances are not wanting in which the presence of the poison has been demonstrated several weeks after death. Thus Brame detected hydrocyanic acid one month after burial in winter; Reichardt, two months after death, in a corpse undergoing putrefaction; and Tillner, four months after death.

Analysis.—The parts which should be first examined are the blood and the contents of the stomach. If death have been rapid the urine will not contain the poison. The material to be examined is subjected to distillation in order to separate the acid in such form that the distinguishing tests may be applied. If the indications do not point very decidedly to hydrocyanic acid the distillation should be combined with the search for phosphorus and other volatile poisons, the tests being applied to the first portions of the distillate. When hydrocyanic acid (or a cyanic poison) only is to be searched for, the apparatus is to be somewhat modified and no precautions with regard to light are necessary. If the material under examination be the contents of the stomach, certain sources of error are to be provided against. In the subsequent distillation in presence of an acid, hydrocyanic acid would be produced if a thiocyanate, usually a normal constituent of the saliva, or potassium ferrocyanid, or the pips of apples, pears, and other fruits were present. The last-named bodies are to be searched for, with the aid of a magnifier if necessary, in a portion of the contents, and, if found, are to be removed from the portion to be analyzed by filtration of the liquid, with the least possible exposure to air. Potassium ferrocyanid may have been taken as such, or it may be present as an impurity of potassium cyanid, and in the latter event, if not separated, would affect the quantitative result with a plus error. A portion of the filtered contents is dialysed, and the dialysate tested for ferrocyanid and thiocyanate by acidulation with hydrochloric acid and the addition of ferric chlorid. A blue precipitate indicates the presence of a ferrocyanid, and a red color in the liquid that of a thiocyanate.

In the absence of ferrocyanids and of thiocyanates the liquids to be examined—blood or contents of the stomach—are diluted, if necessary, with a known volume of water; 100 c.c. of the liquid are introduced into a 200 c.c. flask, connected with a Liebig's condenser, the lower end of which communicates by an air-tight joint with a small tubulated receiver, from the tubulus of which a tube, bent twice at right angles, is in air-tight communication with one limb of a bulbed **U**-tube. About 20 c.c. of a strong solution of silver nitrate are placed in the receiver and in the bend of the **U**-tube. The 200 c.c. flask is now disconnected from the condenser, enough aqueous solution of tartaric acid added to its contents to render them strongly acid, and the flask again connected with the condenser without loss of time. The flask is supported on a piece of asbestos board, and the distillation is slowly proceeded with until 10 to 15 c.c. of liquid have distilled over, or until the drops of distillate, as they fall into the silver solution, cease to produce any further precipitate. If the distilled liquid contain hydrocyanic acid, a white, caseous precipitate will be formed in the silver solution, the non-formation of which may be considered to be proof of the absence of cyanic poisons. If silver cyanid have formed, it is to be collected with the usual precautions upon a filter, whose dry weight has been determined, washed, dried at 100° C., and weighed. The weight so obtained, minus the weight of the filter, multiplied by 0.20194, gives the weight of hydrocyanic acid (CNH) in the amount of material distilled. The precipitate of silver cyanid is formed in solutions containing one part of CNH in 250,000; beyond that dilution the reaction fails (Link and Möckel).

The filter, with the adherent precipitate, is then placed in a flask, moistened with a few cubic centimetres of water, agitated, treated with 0.74 c.c. of a decinormal hydrochloric acid (3.64 HCl in 1,000) for every 0.01 gm. of silver cyanid found, again thoroughly agitated after corking, allowed to clear by subsidence, and decanted through a filter. The clear liquid so obtained is to be used for the application of the tests described below.

If the materials to be examined contain a ferrocyanid or a thiocyanate the operation is conducted as above directed, except that the material is rendered strongly alkaline with sodium carbonate, in place of acid with tartaric acid. Should the cyanic poison be mercuric cyanid its presence may not be revealed by either of the above methods.

TESTS.—1. *Thiocyanate Test* (Liebig, 1847).—Place a portion of the liquid in a porcelain capsule; add a few drops of a dilute solution of sodium hydroxid and a few drops of a yellow solution of ammonium sulphydrate; evaporate to dryness over the water-bath; add water; acidulate with hydrochloric acid, and then add two or three drops of solution of ferric chlorid. If the liquid contained hydrocyanic acid it will be converted by this treatment into sodium thiocyanate, which, with the ferric salt, gives a fine red color. Finally, add solution of mercuric chlorid, which discharges the red color formed by the thiocyanate, but does not affect a similar color formed by meconic acid.

This is the most delicate of the tests for hydrocyanic acid, a distinct reaction being obtained with a solution of 1 to 4,000,000 (Link and Möckel).

2. *Prussian Blue Test* (Ittner, 1809).—Render a portion of the liquid alkaline by the addition of dilute caustic potash solution, add a few drops of a solution of ferrous sulfate which has become yellow by exposure to air, agitate, and let stand ten minutes. A dirty greenish precipitate is formed. Now add hydrochloric acid in slight excess, warm slightly, and, if no blue or green color be immediately observed, examine again after several hours' standing. In the presence of small quantities of hydrocyanic acid the liquid is colored green, and deposits Prussian blue only after long standing; with larger quantities the liquid is colored blue, and, immediately or after a short time, deposits a flocculent dark-blue precipitate, while the color of the liquid gradually changes to yellow. This test fails (Link and Möckel) when the dilution exceeds 1 to 50,000.

3. *Guaiac Test* (Schönbein, 1868).—Moisten a strip of filter paper with a freshly prepared three-per-cent. alcoholic solution of guaiac, dry, moisten with a drop of 0.05 per cent. solution of cupric sulfate, and then with a drop or two of the suspected solution. In the presence of hydrocyanic acid the paper is colored a beautiful blue. With very concentrated solutions (one per cent.) the reaction is attained by simply bringing the moistened paper over the solution. With highly dilute solutions a larger quantity of the suspected liquid is to be brought upon the paper by slow dropping from a pipette.

A distinct reaction is obtained (Link and Möckel) with a solution of 1 to 3,000,000, or (Hermann) 1 to 120,000,000.

This reaction is of value only as confirmatory of others, or as a preliminary test, as the same appearances are produced by ammonia, volatile ammonium compounds, hydrochloric acid, tobacco smoke, ozone, etc.

4. *Nitroprussid Test* (Vortmann, 1887).—Add a few drops of a sodium nitrite solution, then two or three drops of ferric chlorid solution, and, finally, enough dilute sulfuric acid to cause the brown color to just change to light yellow, heat to boiling, cool, add ammonium hydroxid solution, filter, and add to the filtrate a drop or two of very dilute ammonium hydrosulfid solution. A fine violet color is produced, which passes into blue in a few minutes, then to green, and finally to yellow.

Other tests have been suggested: With starch and potassium iodid (Schönbein); with cupric sulfate alone (Lassaigne); with picric acid (Braun); with cobaltous chlorid (Braun); with mercuric oxid (Henry and Humbert), and with uranic nitrate (C. Lea). These are, however, all inferior to those given above, which are sufficient to characterize hydrocyanic acid with certainty.

CYANIC POISONS OTHER THAN HYDROCYANIC ACID.—What has been said above concerning hydrocyanic acid applies in the main to all substances owing their poisonous qualities to the presence of that acid. A few points, however, of variation or special interest require mention.

Potassium cyanid is at present far more frequently the cause of death than the acid itself, the potency of which is in no way diminished by its being in combination in a soluble salt. The symptoms are those of hydrocyanic acid poisoning, to which, if death do not occur with great rapidity, are added symptoms referable to the corrosive action of the potassium salt—burning pain in all parts with which the corrosive has come in contact. Vomiting is of much more frequent occurrence than in poisoning by hydrocyanic acid.

Potassium cyanid exerts a chemical action upon the skin, and is also readily absorbed through slight abrasions or excoriations. Serious poisonings, and even death, have in many instances resulted in this way in photographers, galvano-platers, or by the handling of plate-polishing powders containing potassium cyanid.

The post-mortem appearances differ markedly from those observed in cases of poisoning by hydrocyanic acid. While in the latter class of cases the autopsy may be said to reveal nothing of moment if the odor be absent, in cases of death from potassium cyanid the appearance of the stomach and intestines is highly characteristic if the poison have been taken in the solid form or in strong solution. Lesser ("Atlas d. gerichtl. Med.," Pl. ix., xiv.) has illustrated the appearances in a typical case. The mucous surface of the stomach is rugous, and of a light purple-red color, fading to a more brownish tint in the pyloric portion. The mucous membrane is more transparent than normal, and the red color is due more to an imbibition of the epithelium with blood pigment altered by the poison than to fulness of the vessels. If the autopsy have been long delayed, post-mortem corrosion may be extensive. In the duodenum, at the pylorus, is a narrow band of normal tissue; below this the mucous membrane is of an intense light-red color, and of greater transparency than normal. The remainder of the small intestine presents portions of normal tissue irregularly alternating with sections which are of the same light-red color as the duodenum, hyperæmic, and marked here and there with patches of extravasation varying in size up to the diameter of a quarter-dollar.

When pure, potassium cyanid contains forty per cent. of hydrocyanic acid. The commercial article usually contains carbonate, and sometimes potassium ferrocyanid, the former frequently in considerable quantity.

Other metallic cyanids, if capable of yielding hydrocyanic acid on contact with an acid in the cold, produce, when taken, the effects of the acid. Those which are decomposed by an acid only with the aid of heat are inert. *Mercuric cyanid* behaves more as a mercurial than as a cyanic poison, having produced effects very similar to those of corrosive sublimate in the few recorded cases. In a recent case in which it was administered, mixed with a powder capable of liberating free hydrobromic acid, it was decomposed and caused death in twenty minutes from cyanic poisoning. The *metallocyanids* are for the most part non-poisonous.

Potassium thiocyanate is possessed of poisonous properties which are, however, referable to the potassium rather than to the acid. *Mercuric thiocyanate* is the material of which the toys called Pharaoh's serpents are made. A few cases of irritant poisoning produced by swallowing these toys have been recorded.

Bitter almonds on contact with water at a slightly elevated temperature produce hydrocyanic acid by decomposition of the amygdalin which they contain. A few cases of poisoning by eating bitter almonds have been recorded. They do not differ from cases of poisoning by small doses of hydrocyanic acid.

Oil of bitter almonds, when insufficiently purified, contains as much as ten to fifteen per cent. of hydrocyanic acid, and, being in common use by confectioners and in the kitchen, is a prolific source of so-called accidental, as well as of suicidal poisoning. The symptoms are similar to those caused by potassium cyanid, and are usually comparatively slow in their development, although in some instances the action has been as rapid as that of hydrocyanic acid. From twenty to forty drops is the probable lethal dose for an adult.

Cherry-laurel water contains about 0.25 per cent. of hydrocyanic acid, and produces effects similar to those of the dilute acid. It is of historical interest, having been used in medical practice and, as a poison, as the precursor of hydrocyanic acid. It was the agent used by Donellan in the murder of Sir Theodosius Boughton, in 1781; and by Price, the last claimant to the discovery of the transmutation of baser metals into gold, to make away with himself, in 1784, when the falsity of his claim was about to be demonstrated.

MEDICO-LEGAL QUESTIONS.—The following points have arisen in trials for murder by prussic acid, and have proved to be the questions upon which the case mainly turned:

1. *Was death due to prussic acid, and not to apoplexy?* As, in the absence of a distinct and unmistakable odor of hydrocyanic acid, there exists no post-mortem appearance which is characteristic of this poison, and as the symptoms in some cases closely resemble those of an apoplectic seizure, it is highly desirable that in cases of suspected poisoning a distinct answer to the above question be had in unmistakable chemical evidence of the presence of the poison in the blood.

There are certain points of symptomatology and of morbid anatomy which are of great value in this connection if they exist. If a person poisoned with hydrocyanic acid do not die within a short time, there occur violent convulsions, with opisthotonus and rigidity of all the muscles. In apoplexy there may be rigidity of an extremity, but never of all the voluntary muscles. But if the poison cause death rapidly, the convulsions do not usually occur.

After death from hydrocyanic acid the meningeal vessels and the cerebral sinuses are found gorged with blood; but never, as in sanguineous apoplexy, is there extravasation of blood into the ventricles, the membranes, or the substance of the brain, nor are there clots.

In a classic French case, "l'affaire Héritier," tried at Cambèry, in 1841, the prisoner was sentenced, and would have been executed had not Orfila shown from the *facts* of the evidence that the death of the deceased, Praslin, was due to apoplexy, and that the *opinions* of the chemical and medical experts upon which the conviction was based were of the most flimsy character, even for that period.

2. *Are certain symptoms and appearances necessarily present?* The argument has been frequently advanced that death could not have been due to hydrocyanic acid because a certain supposed characteristic symptom, such as the shriek, convulsions, or involuntary evacuations, was not observed or could not have occurred.

When rabbits and other animals are poisoned with hydrocyanic acid they usually emit a loud cry or shriek. In some of the earlier trials for poisoning by this substance the defence was raised that death was due to other causes because this cry had not been heard. The records of numerous cases of undoubted death from prussic acid show that in the human subject the occurrence of this cry has not been observed.

Attempts have also been made to argue that death could not have been due to prussic acid because the deceased was found calmly disposed in bed, reposing upon and covered by clean and evenly folded bedclothing, and consequently neither convulsions nor involuntary evacuations could have occurred. Convulsions are not usually observed when large doses of the poison have been taken, and when they do occur they are frequently of a mild type. In the greater number of the many cases in which the body is found without any observation of symptoms having been had, the countenance bears a calm and placid expression, which would not indicate that convulsions had occurred.

Involuntary evacuations of fæces or urine, or both, have occurred in about one-half of the recorded cases.

The characteristic *odor* of hydrocyanic acid, which may be described as that of bitter almonds, does not belong to any other known substance, except the oil of bitter almonds (benzoic aldehyd) and nitrobenzol; the former, in its pure state, a substance only found in chemical laboratories, the latter an active poison.

In some instances of death from the cyanic poisons the odor is easily recognized and distinct. Sometimes it may be observed on entering the apartment in which is the corpse; sometimes, during life, in the expired air, or, after death, at the mouth; sometimes only after opening one of the cavities of the body, or the stomach, or on cutting into the lungs or liver.

When the odor has been *distinctly* recognized by more than one person, its existence is a factor of great moment in the evidence to prove the cause of death: but a failure to detect the odor is by no means of correspondingly great significance in the opposite direction. Several instances are recorded in which analysis has proved the presence of the poison, although the odor could not be distinguished either during life or after death.

3. *Was a person killed by hydrocyanic acid capable of certain voluntary acts?* Because hydrocyanic acid is capable, if taken in sufficient quantity, of destroying the power of voluntary motion almost instantaneously, within a few seconds after having been swallowed, it has been argued that death could not have been suicidal in a case in which the deceased was found in such a position as implied voluntary acts on his part after having taken the poison, or the presence of another person. Numerous cases are recorded, however, in which the person was capable of considerable voluntary effort after having voluntarily taken a dose of hydrocyanic acid sufficient to cause death.

4. *Was the hydrocyanic acid, detected in the body by analysis after death, introduced during life?* is a question which may arise upon a trial for murder by this poison. The defence may adopt either of the following methods of accounting for its presence:

(*a*) *It was introduced after death.*

(*b*) *It was given medicinally.* These claims, if false, are to be met in the same way whatever poison has been used, consequently they require no particular consideration in this place. It cannot be claimed that hydrocyanic acid was used for embalming.

(*c*) *Hydrocyanic acid is a normal constituent of the body.* The only cyanogen compound which has been shown to exist in the normal human body is the thiocyanate of the saliva and urine. If the precautions mentioned above have been taken, this substance cannot be mistaken for hydrocyanic acid.

(*d*) *Hydrocyanic acid is a morbid product of the economy.* Hydrocyanic acid has been, it is claimed, detected in the urine in dropsy (Brugnatelli), typhus, cholera, and hepatitis (Fourcroy, Osborn), and in the fluid of ascites (Goldefy-Dorhs). Although Buchner admits the possibility of the formation of hydrocyanic acid in certain pathological processes, Husemann very properly considers that, even if these somewhat doubtful observations be accepted, they have no forensic interest, as it is not in the urine or in pathological exudations that prussic acid is found in cases of poisoning.

(*e*) *Hydrocyanic acid is a product of putrefaction.* This argument was advanced by the defence in two English trials, cited by Taylor, and is based solely upon opinion. Several writers upon toxicology—Orfila, Buchner, Bonjean, Preyer—admit the *possibility* that hydrocyanic acid *may be* one of the numerous products of putrefaction, yet no writer has yet asserted that it *is* so produced, and numberless analyses of contents of stomach, blood, etc., in every stage of decomposition, have been made by many chemists without any evidence of its presence.

Rudolph A. Witthaus.

HYDROCYANIC ETHER.—This body, chemically *ethyl cyanide*, $C_2H_5.CN$, is a colorless ethereal fluid miscible with water, alcohol, and ether, and possessed of poisonous properties analogous to those of hydrocyanic acid. It is not used in medicine. *Edward Curtis.*

HYDROFLUORIC ACID.—Hydrofluoric acid is a pungent, corrosive gas, very soluble in water. The acid of commerce is an aqueous solution containing from thirty-six to thirty-eight per cent. of the anhydrous acid; it emits fumes which are extremely irritating. When applied to the skin it destroys the epithelium and underlying tissue, rendering the parts hard and structureless.

Hydrofluoric acid is an efficient bactericide and antiseptic, and for this purpose Dujardin-Beaumetz advocated its employment in the treatment of tuberculosis by inhalation. He vaporized one grain in an air-tight compartment of the capacity of 22 cubic metres. In this the patient is placed for an hour daily, the period being gradually prolonged. In some instances the results were very favorable, but in others it produced an irritation of the lungs and increased the pulmonary trouble. Inhalations have also been used in diphtheria and whooping-cough. In the latter much benefit is reported from the use of a tablespoonful in a quart of water, in an inhaler, every second day.

Internally, hydrofluoric acid is a marked depressant, acting upon the vaso-motors and lowering the force and frequency of the pulse. In excessive doses it causes death by profound collapse and failure of respiration.

As a vaso-motor dilator its employment has been suggested in chronic rheumatism, epilepsy, and goitre. In the latter condition it was thought to be of especial value by Woakes, of London, but it has not proved to be of much service.

The alkaline fluorides are selected for internal administration. The fluoride of sodium or of potassium in doses of one grain are quite unirritating, and may be used for a prolonged period.

Locally, solutions of the strength of one part in three thousand may be used for ordinary antiseptic purposes. Under the title of *fluorol*, sodium fluoride has been used in a two-per-cent. solution to replace perchloride of mercury. The solutions are unirritating and free from any toxic action. A half-per-cent. solution may be used for the eye. *Beaumont Small.*

HYDROGEN DIOXIDE.—Hydrogen dioxide, H_2O_2, commonly called *peroxide of hydrogen*, is formed by reaction between barium dioxide and mineral acids in the cold. Obtained in concentrated condition, this body appears as a colorless, transparent, heavy, oily fluid, of specific gravity 1.452, neutral to test paper, remaining fluid at temperatures far below the freezing point of water, but rapidly and even explosively suffering decomposition into water and gaseous oxygen upon even a slight elevation of temperature, or upon contact with charcoal and certain metals and oxides. Even at ordinary temperatures the same decomposition occurs spontaneously to a greater or less extent.

Hydrogen dioxide mixes in all proportions with water and dissolves also in ether. As a medicine, it is used in solution in one or other of those fluids, the aqueous solution being commonly known as *oxygenated water*, and the ethereal as *ozonic* or *ozonized ether*. The *aqueous* solution in common use contains three per cent. of hydrogen dioxide by weight, a strength representing a charge of ten volumes of oxygen to one of the water of the solution. Such a solution is official in the United States Pharmacopœia under the title *Aqua Hydrogenii Dioxidi*, Solution of Hydrogen Dioxide. It contains a little sulphuric acid, purposely allowed to remain, as a preservative, from the charge of acid used to clarify the solution. This solution is a sparkling, clear, colorless aqueous fluid, odorless, but having an acidulous and disagreeable chlorinous taste, and producing a curious sensation and a soapy froth in the mouth, through evolution of oxygen. Its specific gravity ranges from 1.006 to 1.012 at ordinary temperatures. It tends to decompose spontaneously into water and oxygen, and accordingly will deteriorate by age, especially if exposed to light or to warmth. If subjected to evaporation at a temperature not exceeding 140° F. the solution will gain in strength through loss of water, but if heated rapidly it is liable to decompose at once and with explosive violence. Because of these various properties, the solution should be kept in dark amber-colored bottles, *loosely* stoppered and in a cool place. A tight stopper may be blown violently from the bottle, or the bottle itself may be burst, if the stopper be immovably seated. Furthermore, since deterioration by keeping is inevitable, a freshly made sample should be procured always, when possible, for use. Old specimens will certainly be under standard in strength, and even may be wholly spoiled and inert.

Solution of hydrogen dioxide is neither corrosive nor poisonous, and is irritant only to especially sensitive parts, such as the eyes, the urethra, or raw surfaces. Its use in medicine is because of its ready decomposition, with yield of free oxygen. Such decomposition is determined by mere contact of the solution with many things, among which are the organic matters found in blood, mucus, pus, and other morbid discharges, diphtheritic membrane, the bodies of pathogenic micro-organisms, and decaying organic substances generally. It coagulates albumen powerfully. By virtue of the yield of oxygen the solution destroys, by oxidation, the morbific quality of animal secretions and excretions. When added to pus, brisk effervescence ensues and the pus corpuscles are quickly disintegrated. Similarly, when washed over a secreting surface, frothing occurs, crusts of dried secretion are loosened, and foul odors disappear. The foaming will continue till all adhering pus or mucopus is destroyed, when, after washing, the surface will be found to be perfectly cleansed and of healthy appearance. Solution of hydrogen dioxide is thus powerfully detergent and disinfectant to all styles of morbid surface conditions, whether of skin, mucous or serous membrane, or wounds or ulcers. The action, however, is evanescent and does not seem to include any intrinsic healing virtue, such as is shown by silver nitrate. For ordinary purposes, the pharmacopœial ten-volume solution may be used in full strength, but for application to sensitive surfaces such as the eye, the upper nasal passages, or the urethra, it should be diluted with from one to four or more parts of water. It may be applied by swabbing, by injection, or by spraying, but only instruments or utensils of hard rubber, glass, or porcelain should be allowed contact with the solution. To affect the surfaces of the stomach or intestines the solution may be given, without fear, by swallowing or by enema. From one to two or three teaspoonfuls may be given at a dose by the mouth. This dose should be well diluted with water and taken from a vessel of porcelain or glass. Other medicines should not be combined with the solution.

Attempts have been made to utilize the solution of hydrogen dioxide as an oxidizing agent within the system for the cure of disease. But when given by swallowing, a dose of the solution is almost wholly decomposed in the stomach, and, when administered hypodermatically, similar decomposition takes place at once in the juices of the part receiving the charge. In either case, therefore, but little of the solution can enter the blood unchanged, so that there is at best but small chance for a constitutional effect of any moment. If injected into the veins, the solution is instantly decomposed by the blood, and, in cases in which this procedure has been tried upon animals, it has often been followed quickly by death from embolism, due to coagulation of the blood by the disengaged oxygen.

Aqueous solutions of hydrogen dioxide stronger than that of the Pharmacopœia are to be found in the market (so-called "hydrozone"), and also solutions with glycerin as the basis (so-called "glycozone"), and solutions in ether ("ozonic ether": "pyrozone"). The ethereal solution is, naturally, highly inflammable.

Solutions of hydrogen dioxide *bleach* powerfully, and are much used for such purpose. *Edward Curtis.*

HYDROPERICARDIUM: DROPSY OF THE PERICARDIUM.—By hydropericardium is meant a collection of non-inflammatory fluid in the pericardial sac. It is distinctly a transudate and not an exudate. Some authorities include all collections of fluid in the pericardium, inflammatory and non-inflammatory, under this one term. By general consent, however, hydropericardium and hydrothorax are understood to mean transudates. A few cubic centimetres of fluid are practically always found in the pericardial sac after death. The fact that the amount varies with the lapse of time before the autopsy,—the longer the wait, the larger the amount of fluid,—suggests that most of this fluid is a post-mortem transudate. It may amount to even two or three ounces. Not until the fluid exceeds 100 c.c. (about three ounces) is the condition spoken of as hydropericardium.

Anatomic Alterations.—Like transudates in other parts of the body, this fluid is light yellow, or slightly greenish-yellow in color, usually clear, of low specific gravity, and containing few formed elements. There may be some floccules of coagulated albumin. It may contain urea or bile, especially in renal and hepatic diseases. The percentage of albumin, according to Reuss, is less than in pleural transudates, and greater than in peritoneal transudates. The quantity of fluid varies very much, depending on many circumstances. It may reach from 500 to 750 c.c. Corvisart has reported the enormous quantity of eight pounds—about 4,000 c.c.

The pericardial sac is distended according to the amount of fluid; in the large collections the lungs are compressed and the diaphragm is forced downward. The pericardium proper is thinned, or if the case is of long duration may be thickened. In chronic cases, the subserous fat about the heart disappears, the subserous cellular tissue appears œdematous, and the endothelia are relaxed, swollen, and of granular opacity. The muscular substance of the heart is pale and flabby.

Scientific opinion is as yet divided in the explanation of the presence of transudates. By many transudation is considered a process of filtration; others hold that the capillary walls are to be regarded as living organs, with a capacity for secretion, under the stimulating influence of irritating substances in the blood.

Etiology.—Hydropericardium is never a primary disease, but always secondary to some other disease. In comparison with the frequency of similar collections of fluid in the pleural and abdominal cavities, and the subcutaneous tissues, it is a rare condition. The explanation of this fact probably lies in the incessant activity of the heart. It occurs occasionally as a very rapid collection of fluid in some cases of acute nephritis, as in scarlatinal nephritis. Most commonly it is a part of a chronic dropsy associated with diseases of the heart and kidneys. Less commonly it is found in the various cachexias which produce an anæmic condition of the blood, such as tuberculosis, cancer, scurvy, and the severe anæmias. In these diseases the pericardial dropsy almost always follows transudation into the pleural cavity. Very rarely the dropsy has a predilection for the pericardial sac, rather than for its usual locations. Probably some local alterations in the pericardium would explain this. It may occur as a result of some local interference with the circulation, which hinders the return flow in the pericardial or cardiac veins. Atheroma of the coronary arteries, aneurism, disease of the lungs, pleura, or the heart itself, tumors and inflammations of the mediastinum, all may impede the circulation in these veins. In rare cases the sudden development of a pneumothorax is followed by hydropericardium.

Symptoms.—These are very indefinite, and can scarcely be separated from those of the associated disease. The condition comes on insidiously and would not be recognized were it not for careful physical examination. A familiarity with the possible complications of chronic heart and kidney disease puts the physician on his guard. The dyspnœa and cardiac distress rarely may be chiefly dependent upon the hydropericardium. There is never any acute præcordial pain, as in inflammation of the pericardium. Pericardial friction sounds are never present. If the fluid is large in amount compression of the lungs may add to the dyspnœa.

Physical Signs.—The reader is referred to the article on *Pericarditis* for a discussion of these, as they are the same except for the fact referred to above—viz., that pericardial friction sounds are never present in hydropericardium, either before the collection or after the absorption of the fluid. The transudate is said to move more quickly with change of body position than the inflammatory exudate.

PROGNOSIS.—It is always grave because of the fundamental disease. The fluid in the pericardium adds an extra impediment to the already weak heart and thus hastens the fatal issue. In rare cases, as in the effusions associated with acute nephritis, there may be recovery.

TREATMENT.—This consists, in the majority of cases, in the treatment of the primary disease, with cardiac tonics and diuretics. Usually paracentesis only delays the fatal issue a short time. However, in rare cases it may be distinctly useful—*e.g.*, when the patient seems to be dying as a result of great local obstruction in the pericardium, which is overwhelming the heart. The operation is not difficult, but must never be undertaken, unless the diagnosis be certain. For a description of the operation see the article on *Pericarditis.*

James Rae Arneill.

HYDROQUINONE.—Hydroquinone, or *hydrochinon,* as it is called by German authors, is chemically *paradioxybenzene,* $C_6H_4(OH)_2$, one of a trio of isomeric diatomic phenols, of which resorcin and pyrocatechin are the other two members. Hydroquinone appears in transparent, colorless, rhombic plates or prisms, fusible at 169° C. (336.2° F.), and subliming without decomposition. The crystals dissolve readily in alcohol, ether, and hot water, but in not less than seventeen parts of cold water. The reaction is neutral and the taste slightly bitter.

Hydroquinone has been proposed as an antipyretic. It is capable of producing convulsions and other derangements in the lower animals, but in therapeutic doses, in man, operates as a speedy, but transient, antipyretic in fever. In such operation the medicine is remarkably well borne, even so large a dose as forty grains producing no derangement worse than a very transient feeling of fulness in the head and slight giddiness, and ordinary doses being free from even this effect. The fall of temperature begins, as a rule, within half an hour after administration of a single dose, reaches its maximum in from two to two and a half hours, and the ensuing rise attains the original temperature in from one to two hours additional. For a transient impression such as described, a dose of from 1.00 to 1.33 gm. (from fifteen to twenty grains) suffices, while for a continuous one, three or four such doses should be given during the twenty-four hours. During continuous medication with hydroquinone the urine may appear of a dark-brown color, due to the presence of products of decomposition of the medicine.

Edward Curtis.

HYDROTHERAPY.—In the present enlightened era of medicine the chief aim of the physician is to aid the inherent powers of the human organism to eliminate morbific agents and reinstate the disturbed equilibrium of the economy, by all means which enhance the patient's capacity to resist the inroads of disease. In the accomplishment of the latter water plays an important part The simplicity of this remedial agent and the neglect of precision in its application have been the chief obstacles in the way of its more universal acceptance. The fact that water is one of the few remedies which has survived since the day of Hippocrates and has been advocated and used by the most eminent physicians of every time, was the writer's incentive to its investigation twenty-five years ago. The clinical results obtained by him have won his highest esteem, especially since he discovered that its action is based upon recognized physiological principles. The latter must be clearly understood before the real value of hydrotherapy can be appreciated.

The action of water upon the human organism is derived from its physical and mechanical effects.

The physical qualities of water are utilized in hydrotherapy because it is an excellent vehicle for conveying the thermic and mechanical effects aimed at. Water absorbs and gives up heat readily; it may be used in solid, liquid, or gaseous form; it may be applied to any limited part of the body or to its entire surface. Hence its physical property alone makes it a most flexible therapeutic agent.

Thermic agents affect living tissues in the most pronounced manner. Smooth muscular fibre contracts under cold and expands under heat, and its contractility may be entirely destroyed by an excess of either. By the conveyance of cold or heat by means of water we are, therefore, enabled to produce striking effects upon vital processes which depend upon muscular activity. As cold and heat are irritants, their reflex effects conveyed through the nervous system also become valuable therapeutically. Applying these axiomatic principles, we find that circulation, respiration, tissue change, and heat production may be positively influenced by the application of water as a medium of conveyance of cold and heat, and that abnormal conditions of the functions may be remedied and their healthy equilibrium restored. That such effects are really produced, laboratory experiment as well as observation at the bedside has again and again demonstrated.

In my book on hydrotherapy * many experiments are detailed showing the influence of hydriatic procedures upon the calibre of blood-vessels, the action of the heart, and even upon the composition of the blood, the respiration, and the secretions. All applications of cold involving the entire surface of the body, or a considerable part thereof, result in an increase of the number of blood cells; the percentage of hæmoglobin and the specific gravity of the blood are also increased when reaction, manifested by cutaneous hyperæmia, ensues. When reaction fails, the erythrocytes, and often the leucocytes also, are diminished.

That these effects may be utilized to explain the rationale of cold applications in disease has been often demonstrated. For instance, Thayer, of Johns Hopkins University, observed that the blood drawn from the lobe of the ear of a typhoid-fever patient after a Brand bath, contained three times the number of leucocytes, ascertained by actual count to be present previous to the bath. This has been confirmed by Winternitz, Breitenbach, myself, and others, in chronic cases and in healthy persons. Since this enormous increase could not be the result of new production during the fifteen-minute bath, the conclusion is inevitable that the increased activity of the circulation, induced by the changing anæmia and hyperæmia of the cutaneous surface resulting from the cold bath and friction, has driven these cells from their hiding-places on the outskirts of the blood stream and elsewhere, and has brought them into active service.

Cold improves the muscular tone of the vessels, *i.e.*, it increases tension; warmth relaxes, causing passive dilatation and loss of tone. Although both produce a hyperæmia, one is the result of reaction and is tonic, while the other is the result of relaxation and is atonic. This trite fact is sadly disregarded in practice. Its more general recognition will do much to neutralize and remove the fear of shock from cold applications in atonic conditions.

The reflex effect of cold and heat conveyed from the skin to the central and sympathetic system, thence to organs and tissues, is an important therapeutic factor, and demonstrates that the thermic action of water upon the human organism is capable of influencing its every part and function in the most pronounced manner.

By guiding and directing these well-ascertained effects of cold and heat, as conveyed by water to the skin, we may evoke changes in the circulation, remove stasis in one and fill another vascular area, deplete others, and thus aid powerfully in removing pathological states.

Water may be applied with accurate dosage by varying the temperature, duration, and pressure. A very high or a very low temperature produces destruction of tissue, while cold and moderately hot water produce a rubefacient effect. Water driven under high pressure destroys tissues, and under moderate pressure causes rubefacient or stimulating effects.

There are also various modifications in hydriatric technique which must be clearly understood before we employ hydrotherapy in disease.

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* "The Principles and Practice of Hydrotherapy," William Wood & Co.

Technique.—It is the aim of this article to simplify hydrotherapy and render it accessible to the general practitioner. Minute attention to details is the first essential for the successful application of all hydriatric procedures; without this, failure is sure to ensue. The following procedures are best adapted for the application of water in disease: Ablution, affusion, sheet bath, drip sheet, compresses, wet pack, tub bath, douche. Their application in various diseases will be shown.

Ablution consists of the application of water by the hand, or with a wash cloth, over successive parts of the body. The method and the temperature of the water vary with the object in view. In febrile conditions the chest, the back, the abdomen, and the lower extremities as far down as the knees are successively bathed every two or three hours, beginning at 75° and reducing the temperature by one degree at each application until 60° F. is reached. It is important to avoid chilling and to bear in mind that reaction is aimed at.

In chronic affections the ablution is a useful preliminary to the more active hydriatric procedures. The patient is first warmed by being snugly wrapped nude, in two long-haired woollen blankets, like a mummy, for one hour. The face is bathed in water of 60° F.; the blankets are successively opened over his chest, abdomen, back, lower extremities to the knees, and these are bathed with the hand, each part being immediately dried and replaced under cover. A general dry rubbing with a woollen cloth, or the hand, follows.

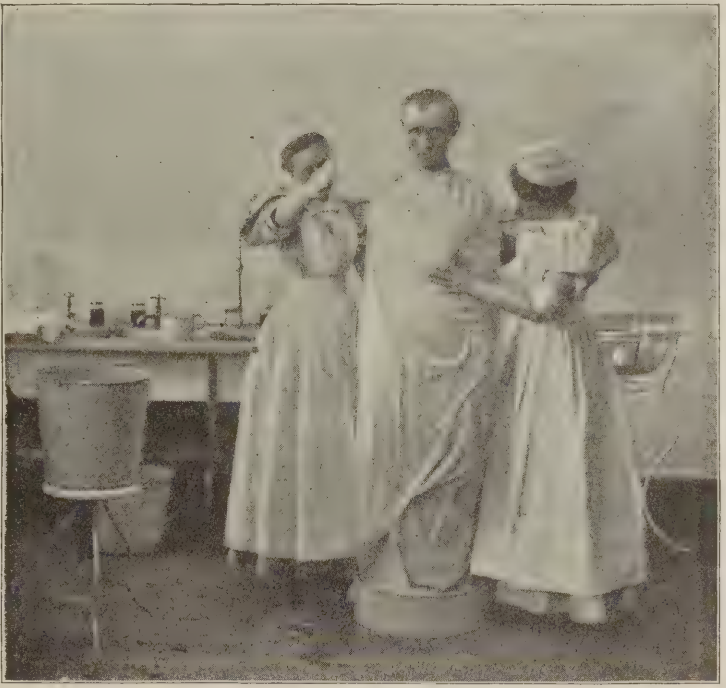

FIG. 2756.—Drip Sheet Mode of Friction.

For the General Ablution the patient stands in twelve inches of water at 95° to 100° F., and is rapidly washed down with the hands, while water—of a temperature of 80° F. at first, but on each succeeding day of a little lower temperature until 60° F. is reached—is poured upon him with the hand or from a vessel. Afterward he should be subjected to gentle friction. Reaction must always be produced.

The *rationale* of the action of ablutions may be found in the gentle shock and reactive stimulus, which is refreshing. The superficial capillaries are dilated, as evidenced by the rosy hue of the skin following ablution with friction, the inspiration is deepened, and cardiac action is bettered.

Affusion.—Having a wet cloth around the head, the patient, sitting or standing in a tub containing twelve inches of water at 100° F., receives a broad stream of water poured with force from a basin, bucket, or pitcher. According to the height from which the water is poured and the lowness of the temperature will be the stimulating effect. The affusion is useful in coma and in stuporous delirium, indicating adynamia and nerve prostration. By this method Currie made his remarkable cures in typhus fever, using chiefly sea water, the patients lying on the deck. In *scarlatina,* when the system is overwhelmed by the poison, the circulation embarrassed, the skin pale or marbled or cyanotic, the respiration shallow, temperature high, pulse rapid and feeble, truly marvellous results may be obtained by the judicious use of brief affusions. Reaction occurs rapidly, and with it come an improved peripheral and general circulation, deepened inspiration, bright countenance, and roseate skin. Rapid affusions of water at a temperature of from 70° to 60° F., have, in my experience, saved lives in these desperate cases.

Sheet Bath.—A rubber sheet covered by a blanket is laid upon one-half of the bed. A linen sheet is now dipped into water having a temperature of from 60° to 70° F., according to the effect desired, and, *without being wrung out,* is laid upon the blanket; the patient, whose face has been bathed with ice-water, and upon whose head a wet cloth is placed, is moved over to the wet sheet, which is wrapped snugly around him. The first impression will be a surprise—called shock—to the cutaneous nerves. Reaction ensues from the patient's own temperature, and its establishment is aided by the manipulations of the nurse, who, with out-stretched hands, gently but firmly sweeps over the wet sheet, omitting the legs and forearms. So soon as one part of the body becomes thoroughly warmed, water from 50° to 60° is poured from a cup or squeezed from a sponge over it, until it again cools. These passes, or frictions, are alternated with the pouring on of small quantities of cold water, until the entire body feels cooled or the patient shivers. Rigor must always be avoided, because it is an evidence of contraction of the vessels. As the friction prevents this objectionable feature of all cold baths we have in the sheet bath an admirable roborant antipyretic, the effect of which may be greatly enhanced by allowing the patient to remain in it, after wrapping him in the blanket, for half an hour. Its mildness as compared with the full cold baths, for which it is an excellent substitute, renders it more acceptable to the patient and his friends, and it may thus be utilized as a valuable initiatory antipyretic measure. It is applicable in all acute diseases in which an elevated temperature is a leading manifestation.

Drip Sheet (Fig. 2756).—In chronic cases the sheet bath is a useful adjunct, and in many cases an important element of the treatment—as, for example, in phthisis, in neurasthenia, and in chlorosis. Here it is called a drip sheet, and is applied while the patient stands in water of 100° F.

The flexibility and simplicity of the method commend it especially. By wringing the sheet well out (cold rub), or by using a coarser sheet, or a lower temperature, for a short time, or by slapping with the wet sheet, instead of simply rubbing the hand over it, the local excitation of the cutaneous nerves and vessels may be enhanced. By saturating it with more water, the antipyretic effect is increased, and this may be still more intensified by a more prolonged application.

The compress is made by cutting four folds of old linen to fit the part. The cloth is more or less wrung out of water at or a little above 60° F. and secured by a flannel bandage wider than the cloth. For tonsillitis it is very useful if applied, not around the neck but from ear to ear and secured by a flannel bandage pinned on top of the head. For articular rheumatism a compress snugly secured by a thin flannel bandage of one layer hastens recovery. In pneumonia the compress, surrounding the thorax like a vest and secured over the shoulder and around the chest by pins, is of paramount value. The abdominal compress is useful in all fevers, as is the trunk compress, enveloping the entire trunk. Compresses are usually renewed every hour in acute cases, and always covered by one layer of flannel to permit evaporation—never covered by oiled silk, which would convert them into a poultice.

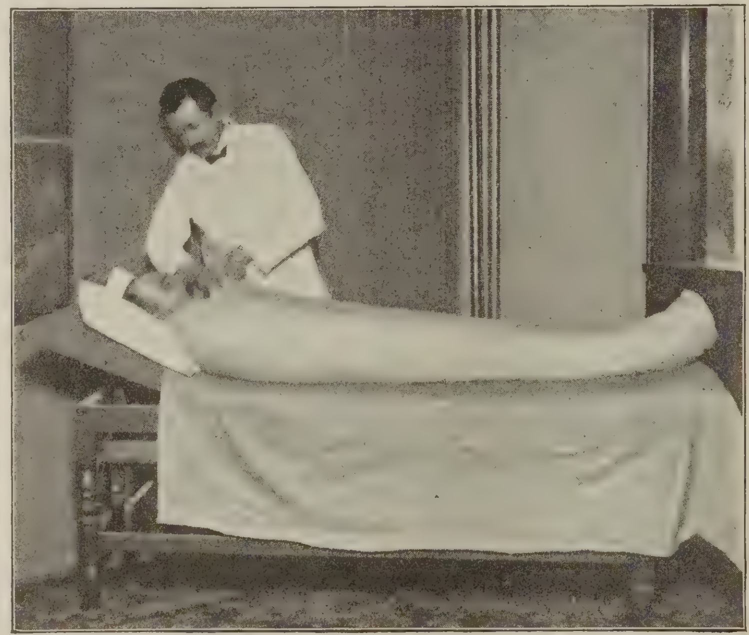

Fig. 2757.—Wet Pack, Showing Method of Tightening Blanket Around Neck.

The Ice Bag may here be referred to. This should always be covered with flannel and never allowed to remain continuously for a longer time than forty-five minutes. It should be replaced at the end of fifteen minutes. Its utility in internal hemorrhages is fallacious, because the blood is driven from the surface into the collateral circulation beneath. Its beneficial effect as an antipyretic for parts situated deeply is fallacious, as proved by the experiments of W. Gilman Thompson and others. The same remark holds true for the ice coil. As an application in feeble and irregular heart action the ice bag is invaluable, if reaction is permitted. The ice coil is a fallacious procedure in fevers, because it cools only the parts beneath it, making them cyanotic, and therefore retards the circulation.

Wet Pack.—A large woollen blanket is spread upon a mattress. Upon this is spread smoothly a linen sheet, *wrung out* of water of a temperature of from 50° to 70° F., according to the nature of the case; the blanket should be long enough to extend from the nucha to a foot or more beyond the patient's extremities. The patient, with a wet cap upon his head, places himself upon the sheet, with his arms raised from the body. One-half of the sheet is now rapidly folded around his body and pressed between the arms. It is snugly secured around the neck and beyond the feet. The blanket is now drawn firmly from the left and tucked under the right side of the body, the right border of the blanket being drawn over to the left in the same manner; then, finally, it should be secured firmly under the body and around the neck, and should be folded over the feet (Fig. 2757). *Success depends upon exclusion of the air by the blanket cover.* If the latter has been skilfully applied, the patient will resemble a mummy, and will get warm in an hour or less.

The wet pack must be followed by some hydriatric method which restores tone to the cutaneous vessels which have been relaxed by it. A sheet bath or a cold affusion will serve this purpose.

The cold sheet produces irritation of the cutaneous nerves, and contraction of the peripheral vessels, and the latter state persists until reaction ensues. Inasmuch as no mechanical aid is given by the attendants, the reaction must depend entirely upon the vital powers of the patient. As soon as the first shock is over—which lasts from five to twenty minutes, and sometimes produces shivering—the cutaneous vessels begin to dilate, and the temperatures of the skin and of the sheet approach equality. This equalization of the two temperatures occurs quickly in fever patients, and slowly in persons having a normal temperature. The sheet bath is, therefore, superior to the wet pack as an antithermic procedure. Many failures are due to the use of the wet pack in fever; it is far more useful in chronic cases.

In chronic diseases the patient is wrapped in a sheet wrung out of water at from 60° to 70° F. as indicated; the higher temperature being employed at first and this being gradually reduced by one or two degrees at each succeeding treatment. Lying for an hour in this pack the patient's body is enveloped in a vapor of its own creation. The reactive labor thus involved is a great benefit to the circulation, and it has been demonstrated to aid in enhancing tissue metamorphosis. The patient often falls asleep. The calming effect of an hour's sleep in the wet pack is valuable in functional neuroses, hysteria, and some heart troubles. It is superior to the hot pack in insomnia and excited mental states.

The therapeutic application of the wet pack is extensive, the procedure being valuable in all chronic cases in which defective tissue metamorphosis is a prominent element, as in *diabetes, rheumatism, gout, anæmia, chlorosis*, and some disorders of the digestive apparatus.

The Full Bath.—A tin tub six feet long, and filled to three-fourths of its depth with water at a temperature of from 80° to 65° F., is placed near the patient's bed in acute cases and shut out from view by a screen. A double blanket covered by a linen sheet is spread upon the side of the bed to be occupied by the patient after the bath, the pillow being covered by a towel. The patient now receives a cup of hot black coffee. He is undressed and a light napkin is applied over the sexual organs. His face is bathed with ice-water, and, if too feeble to step into the bath, he is lifted into it by two assistants, preferably on a small hammock, from which the sticks have been removed. With the greatest gentleness and least fuss he is lowered into the water. He gasps and shudders a moment, or perhaps cries out. But gentle reassurance by word and deed, a calm demeanor, devoid of haste, and the absence of all actual force or argument will quiet him. Friends or relatives must be kept out of the room. An air cushion suspended at the head of the tub will make a head rest, and a large water cushion ring makes a comfortable support for his nates. Two nurses must constantly practise good friction or chafing over *successive* parts of the body. These frictions are of *supreme importance* in preventing chilling, collapse, cyanosis, and heart failure. The effect of the continuous gentle chafing is a suffused redness, which demonstrates that the calibre of the cutaneous vessels is considerably enlarged. As this is being done in successive parts of the body, we really manage to maintain a constant contraction and dilatation of the peripheral vessels, the former being accomplished by the contact with the cold water in motion, the latter by the friction and its attendant reaction. Complaints of chilliness must not be regarded as an indication for removal of the patient from the bath, unless they be accompanied by decided chattering of the teeth, or the face becomes cyanotic. Several times during the bath, which usually lasts fifteen minutes, a basin of water at 50° F. is gently poured over the patient's head and shoulders. If the patient is somnolent or delirious, several basins of cold water are poured over head and shoulders. The bath being finished, the patient is gently lifted out, the napkin covering the sexual organs rapidly dropped, and he is placed upon the previously prepared linen sheet, so that the upper edge extends above his shoulders to the nucha. He is now carefully wrapped in the sheet, a fold being pressed in between the arms and the body and between the lower extremities. The blanket is now wrapped around the patient. If the body temperature has been high, above 103° F., in the rectum, the patient is allowed to lie in the sheet for five or ten minutes; if the temperature is lower he should be at once dried with the sheet and afterward with soft towels. In either case hot bottles are to be placed against the feet. Usually the patient will fall asleep.

When a bath having a temperature of from 70° to 65° F. is given every three hours in the case of a patient who has a rectal temperature of 103° F., this may be looked upon as the ideal bath designed by Ernest Brand, of Stettin, for the treatment of typhoid fever.

In the case of the graduated bath, devised by von Ziemssen, the preparation for bathing and drying the patient is the same as in the Brand bath. The tub is filled with water at 90° F. Colder water is added for half an hour until the water temperature reaches 68° F. *Chafing is here also an all-important element of the bath.* The patient is wrapped in a prepared sheet and blanket without being dried, for a quarter of an hour, and then he is dried and his clothing replaced.

The rationale of the cold baths, which have been chiefly applied in typhoid and other infectious fevers, is so exact and scientific that it must lend firmness born of conviction to the attendant who applies them with a clear understanding of their aims and capabilities. The nervous system is overwhelmed by toxæmia. An indefinable malaise is followed by ataxia, general lassitude, somnolence, and other adynamic manifestations, which culminate in severe cases in stupor, delirium and coma, subsultus, tremor, etc. The heart, being called upon to do extra duty, threatens to fail, and often does fail, not owing to the elevated temperature only, but to a paretic condition of the capillary circulation, induced by the infective process, which embarrasses the propulsive action of the cutaneous arterioles.

The depreciated condition of the nerve centres, which in typhoid and similar fevers is the leading point of attack, must be the leading point of defence. From it originates a condition of the circulation which, by its effect upon the peripheral vessels, not only disturbs heat radiation, and thus develops temperature elevation, tympanites, etc., but later gives rise to other most perilous conditions, such as failure of the heart, local hypostases, bed-sores, etc. The stimulating, refreshing effect of cold water and friction upon the terminal fibrillæ of the sensory cutaneous nerves is conveyed to the central nervous system; the gasp emitted by the patient is evidence of a reflex effect. The cutaneous arterioles are stimulated and dilated in reaction, filling with cooled blood, and thus the heart, laboring ineffectively to overcome these paretic conditions, is afforded some relief. Elastic resistance at the periphery being thus increased, the ventricular contraction becomes more complete, and the blood courses with increased vigor through the entire organism. Excretion is enhanced, and the vitality of the patient rises. The patient's condition is the best evidence that these effects are salutary. He who has witnessed the dull eye of a typhoid patient glisten after a cold friction bath, who has felt the dicrotic pulse rebound, who has seen the apathetic countenance brighten, the urine increase, and slumber ensue, must be convinced of the value of cold procedures in infectious fevers. Reaction must always be induced by friction during the bath.

In Typhoid Fever, the Brand bath, above described, is of the greatest value, as clearly shown by the only absolutely reliable medical statistics extant. Dr. Vogl, medical director of the Bavarian army, has published the records of a period of forty years, covering all types of epidemics of typhoid fever and all kinds of treatment; and according to these statistics, based upon 8,500 cases of the disease occurring in soldiers, the mortality has been reduced, by the Brand bath, from twenty-two per cent. down to three per cent. The subjects being all of the same sex, occupation, age, and environment, and the inquiry covering large numbers and a long period, these statistics are unique and absolutely reliable.

The writer's method of procedure is as follows: When he suspects that he is dealing with a case of typhoid fever he proceeds at once to use ablutions every two or three hours, applies an abdominal compress between the ablutions, and then orders a sheet bath of from 80° to 70° F. On the fourth day he orders a friction bath at 90° for fifteen minutes, as above described, to be succeeded in four hours by others at 85°, 80°, 75°, and 70° F. These may be taken in the bath-room. When the diagnosis becomes positive the baths must be administered in a six-foot tin tub, placed alongside of the bed, eighteen inches from the floor. The temperature of the bath should never be less than 65° F., but cold enough to produce good reaction —70° to 75° F. being the average. Active friction must be continued for fifteen minutes, and affusions given as above described. This is the Brand bath given every four hours as long as the rectal temperature registers 103° F. Abdominal compresses at 60° F. are always applied between the baths. When this bath cannot for any reason be obtained, the *sheet bath* is an excellent substitute, because it furnishes the thermic excitation and the reaction is furthered by friction over the sheet. A *towel bath* is also useful when the sheet bath is positively inapplicable. This consists of a towel smoothed, dripping, over the back and successively over the glutei and the front of the body, and friction with a block of ice held in gauze, until each part is cooled. The patient is dried and left to rest. This may be repeated every two or three hours. All cold baths must be given with friction, and chattering of the teeth and cyanosis must be avoided.

In Scarlet Fever and Measles the tub bath of 90° F. gradually reduced to 85° F. without friction, continued for from eight to twelve minutes, and repeated every four hours, is soothing and antithermic.

Pneumonia.—Happily, the day of fighting pneumonia as a disease is passing away. The enlightened practitioner prepares the pneumonia patient by providing him with a comfortable bed, pure air, easily assimilated food and drink, and good nursing. He no longer relies upon aconite, veratrum, quinine, repeated antipyretics, morphine, stimulants, and stuffing, because he recognizes these to be impedimenta, when the patient should be stripped for the fight. They embarrass the eliminating function, impair the appetite, and cripple his resources. The application of cold water, on the contrary, meets all the indications for which these powerful remedies were formerly applied—and it accomplishes it without their depreciating effects. What affords more comfort to a child suffering from pneumonia than a tub bath with good friction in water of 95°, reduced during five to eight minutes to 85° or 80° F.? A few baths of this kind repeated every four to six hours, without fuss or confusion, at the bedside (not in a bath-room), calm the respiration, reduce temperature, promote sleep, slow and strengthen the pulse, and refresh the oppressed nervous system. In the interval between the baths I am in the habit, if the temperature and pulse are high, of wrapping around the upper half of the trunk a compress made of three folds of old linen and wrung out of water at 65° F. and always covered by a wider bandage of one layer of thin flannel (without oiled silk), snugly secured over the compress.

By renewing this compress every hour the good effects of the bath are maintained and their frequent repetition is rendered unnecessary.

In the adult patient the tub bath is not so useful, because it involves more trouble to, and disturbance of, the patient, especially if pleurisy be present. Here the wet compress around the chest, not too firmly wrung out of water at 60° F., usually fills all therapeutic indications. It becomes hot, and when removed the re-application causes a deep inspiration, a betterment of pulse quality, and an increase of urine. The latter is also enhanced by draughts of from four to six ounces of water at 45° F., administered regularly every two hours.

No claim is made that cold water cures the disease. The object of these mild cold procedures is to fortify the patient's resisting powers and thus to aid him in maintaining a successful defence against the disease until its natural limitations are reached. The frequency of application, the temperature of the water, the extent of the saturation of the compress, the duration of the bath, the selection of the procedure, are matters for judgment in each individual case. That we can utilize all these, and thus adapt them to conditions as they arise in each individual case, gives this remedial agent a positive advantage over all others and entitles it to more extensive trial and study than it has received. Large clinical observation is the basis of these views.

The Douche is a procedure by which water is driven upon the patient's body from the nozzle of a hose the internal diameter of which varies from one-eighth to one-half inch. The ordinary shower bath and the needle bath are multiform douches. The water is usually supplied from a reservoir placed at a height of from thirty to seventy feet, and giving a pressure, at the nozzle, of from fifteen to thirty-five pounds to the square inch. A douche table has been devised by the author (1894) by which the temperature, duration, and pressure are regulated before the patient receives the water. This apparatus is useful only in institutions. It has been adopted in the United States (St. Elizabeth) Hospital in Washington and in many other lunatic asylums. It is adapted only to hospitals treating chronic cases in large numbers.*

CHRONIC DISEASES.—Chronic diseases furnish such a favorite field for hydrotherapy that no internal disease should be yielded up as hopeless until this mode of treatment has been systematically tried, in connection with all those hygienic agencies which are usually of more avail than medicinal agents, viz., exercise or rest, diet, drink, clothing, climate, etc.

The general ablution, drip sheet, wet pack, and douche are useful if they are employed in a properly graded manner. Beginning with the general ablution and gradually lowering the temperature, and doing the same with the drip sheet, always producing reaction, and then, if need be, going on to the wet pack, we have a variety of modes and measures which afford great latitude in energizing the system, enhancing its vital capacity so as to throw off the materies morbi or re-establish the equilibrium of the circulation and nerve centres. (See above for technique.)

A case of anæmia, for instance, which has resisted iron, strychnine, malt, digestives, etc., often assumes a different aspect when the neuro-vascular discipline produced by this treatment is secured. The effect of increased oxygenation may be greatly aided by following daily treatment with exercise in the open air. The pallid lips assume a ruddier hue, the languid eye brightens, the step becomes lighter. Appetite and assimilation are improved because of the enhanced hæmatosis and improved circulatory conditions in the gastro-intestinal mucous lining. (For rationale see above.)

Neurasthenia.—A type of cases which I see quite often is that trying class of neurasthenics who wander from one doctor's office to another, and sooner or later become the prey of charlatans. These patients present every phase of depreciated vascular and nerve condition; some are the prey of morbid fears and become the despair of family, friends, and physician. If such a case be subjected to a methodical course of hydrotherapy the result will often prove a revelation, provided there be no organic basis for the malady. If mild procedures do not meet the indications, douches adapted with regard to temperature, duration, and pressure to each individual case, play the most important rôle here. These are capable of arousing the dormant neurons, enhancing vascular activity, and improving general and local nutrition. The cortical centres, which are the chief points of failure in these depressed neurasthenics, feel the impulse of a better circulation and nutrition. The morbid ideas and illusions vanish. The hypochondriacal introspection ceases, and the patient slowly but surely regains his neuro-vascular equilibrium. The results of hydrotherapy in such cases are, in my experience, far more enduring than those following other methods of treatment.

Insomnia is markedly affected by hydriatric measures.

Rheumatism, Sciatica, Gout, Neuritis.—Another set of cases which are greatly benefited by hydrotherapy are those unsatisfactory rheumatic, gouty, and lithæmic conditions which are the bane of the doctor's life and which we are often so glad to rid ourselves of by sending them to the hot springs. These may be very satisfactorily treated at home.

My personal experience with hydrotherapy in chronic diseases extends over a period of ten years and embraces a very large number of cases of the most varied pathological conditions. The application of this method of treatment to such varied diseased conditions is rendered possible by its flexible nature, which enables the physician to adapt it, by modifications of temperature, pressure and duration, and numerous technical details, to the most varied pathological manifestations, provided he has mastered the rationale of its mode of action, and provided the carrying out of the details is not left entirely to the judgment of bath-nurses It would be much better to consult some work on hydrotherapy than trust the latter.

When douches are needed, only institutions under the supervision and direction of a trained physician should be resorted to, for in no other way shall we be likely to avoid the dangers of the empirical application of the procedure, which has so often brought disaster to both and discredit to this remedial agent. *Simon Baruch.*

HYDROXYLAMINE.—This compound base is very unstable and exists only in solution. It is ammonia in which one atom is replaced by the hydroxyl group. The formula is NH_2OH. *Hydroxylamine hydrochloride* forms in colorless crystals resembling ammonium hydrochloride; it is hygroscopic and very soluble in water, alcohol, and glycerin. It possesses active reducing properties, in consequence of which it has been proposed as a substitute for chrysarobin and other reducing agents in the treatment of skin diseases, such as psoriasis, parasitic affections, and in lupus. The disadvantage attending its use is the toxic symptoms that may arise from absorption. These ill effects are due to its reducing action on the hæmoglobin of the blood. It may also prove very irritating to the skin. For ordinary use, a strength of one part in a thousand should be commenced with and increased to one in a hundred, if no local irritation is produced. The application may be made twice or three times a day. *Beaumont Small.*

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* See author's treatise mentioned on p. 788.

HYÈRES AND COSTEBELLE.—Hyères, situated in the department of the Var, is the most southern of all the winter stations along the French Riviera. It is fifty-five miles southeast of Marseilles and seventy-two and a half miles west of Cannes. Unlike the other Mediterranean resorts, it is three miles from the sea, lying at the foot of a steep hill having an elevation of about seven hundred feet. It is sheltered by the mountains from the north and northeast winds, but exposed to the northwest and west winds; hence it suffers, like the other resorts on the coast, from the disagreeable "Mistral," which is especially frequent in February and March. It is less affected by the sea breezes, not only on account of its distance from the sea, but also on account of the protection afforded by the islands lying off the coast—the Isles d'Hyères.

Costebelle, a suburb of Hyères, consisting of a few houses and several hotels surrounded by pine woods, is almost on the coast, so that patients can easily have the change from the more sedative air of Hyères to the more bracing and stimulating atmosphere of the seaside.

The town of Hyères itself contains 17,700 inhabitants, and consists of the old and the new town, the latter being the resort of invalids and visitors,—a place where there are villas, hotels, fine avenues, and public gardens.

The winter climate is mild, dry, and sunny, but, as has been said, there exists the one great disadvantage of the cold northwest wind (mistral). "Favorable as I believe this station to be," says Cazalis, quoted by Burney Yeo, "up to the time that the mistral begins to blow, equally dangerous do I believe it to be from that moment." "It is a most searching wind," says Cormack ("The French Riviera—Hyères as a Health Resort," *The Climatologist*, January 15th, 1892), "and very trying to invalids and those of a nervous temperament. Patients, as a general rule, are much better at home than out of doors while it lasts."

Climatic Data of Hyères. (From Biden and Cormack.)

	November.	December.	January.	February.	March.	April.	Mean of six months.
Temperature—							
Average or normal ..	53.6°	48.0°	47.5°	48.5°	51.0°	55.0°	50.7°
Average range	15.6	15.0	16.5	15.9	17.5	16.1	
Mean of warmest....	61.4	55.5	55.8	56.5	59.8	63.3	58.7
Mean of coldest	45.8	40.5	39.3	40.6	42.3	47.2	42.6
Highest or max.*....	63.7	57.5	57.5	57.5	60.0	66.7	
Lowest or min.*	45.0	40.5	41.2	41.5	44.2	52.2	
Humidity—							
Average or relative..	76%	73%	76%	75%	71%	71%	73.5%
Precipitation—							
Average in inches ...	3.52	2.86	3.08	2.21	2.26	3.11	17.04
Wind (number of days)							
Light to fresh	10	11	9	11	15	16	74
Strong to a gale	2	5	3	3	3	4	22
Weather—							
Days of sunshine per month.............	21	21	23	20	25	23	135
Days on which rain fell................	7	6	6	6	5	7	39
Days calm	16	15	18	13	12	9	84

* At midday and 8 A.M.

In looking over the climatic table of Hyères arranged from data of Drs. Biden and Cormack, it will be observed that the mean average temperature for the months from November to April inclusive, does not vary very much from month to month. Neither do the extremes appear to be very great. The average daily range is large, owing to the rapid fall of the thermometer after sunset, which frequently amounts to as much as seven or eight degrees.

Between the hours of 8 A.M. and 4 P.M., however, says Cormack, the winter temperature may be said to vary between 50° and 59° F. in the shade, and from 75° to 85° F. in the sun. Occasionally the freezing point is reached. The air is moderately dry, as indicated by the relative humidity, and there are no mists. The rainfall is small, and for the six months rain falls on an average only on 39 days.

There is a very large amount of sunshine, an average of 135 days out of a possible 181 days, or three-fourths. There is an average of 22 days of light winds and 22 of strong ones. If the winds, especially the mistral, could only be eliminated, this resort, as indeed the others of the Riviera, which in like manner suffer, would be most delightful; but the health resort is yet to be discovered in which every climatic factor is favorable. As has been referred to in the article upon *Cannes*, the climate of the Riviera, in the writer's opinion, is far inferior to that of southern California, with which it is comparable, especially in temperature, dryness, the amount of sunshine, and, more than all, in regard to the winds. Southern California is free from high, cold winds like the mistral. In Southern California we have, moreover, that degree of equability which is nowhere found on the Riviera.

In like manner comparing the Riviera with southern Florida, we find that the climate of the latter possesses that measure of warmth and equability which is not found in the former, and is free from cold winds, though on the other hand, Florida is considerably moister than the Riviera. Speaking in general of the winter climatic characteristics of Hyères, we may say that they are mildness, purity of air, abundant sunshine, and moderate dryness. On the other hand, the chief feature of an unfavorable nature is the "fearful" mistral. "It rakes the valley from end to end, with no obstacle to stop it or turn it; it blows sometimes for six or seven days together, and nights too!" (Cazalis, quoted by Burney Yeo.) Although cold, this mistral is a very dry wind, and a wind which generally brings fine, clear weather. The air loses its humidity and becomes dry, cold, penetrating, and irritating. As has been before noted, it is not frequent until February or March.

The invalid's day, as given by Cormack (*op. cit.*), is comprised between the hours of 10 A.M. and 3 P.M. for the warmest months, and between 11 A.M. and 3 P.M. when the days are colder. At sunset there is a rapid fall of temperature which renders it dangerous for delicate persons to go out after that time. There is also a marked difference between the sun and shade temperatures, so that it is always wise to be provided with a wrap. The vegetation is luxuriant and varied. "The mountains and hills are covered with trees as green in the winter as in the summer." The orange, olive, and palm trees are seen on every hand. Roses, violets, anemones, hyacinths, etc., are sent in great quantities during the winter to the European markets, and early fruit and vegetables are cultivated for the Paris market. There are many charming and picturesque promenades, and in this respect, says Burney Yeo, Hyères is much better off than most other resorts on the Riviera. The outdoor diversions are many and varied; botanizing, butterfly catching, antiquarian research, boating, fishing,, golf, tennis, etc., are some of them. The valley in which Costebelle is situated is better sheltered from the mistral, and is "enbosomed in pine woods, broken here and there by vineyards and olive orchards. . . . Near the shore there are large groves of olive trees, which are finer than at Hyères itself, and indicate a warmer climate" (Sparks, "The Riviera"). The water supply of Hyères is said to be good and the sanitary condition satisfactory, except in the old portions of the town. The accommodations are good and abundant.

As to the class of invalids for which the climate of Hyères is beneficial, the testimony is conflicting. Cormack says it is "admirably suited for cases of phthisis," while Drs. Sparks, Weber, and Yeo, says Richards, are rather non-committal. In the writer's opinion, the value of this climate for phthisis is very slight, and while there are so many other resorts of approved value for this disease, he would never think of sending a phthisis patient there, for the reason that the cure cannot be a continuous one on account of the heat in summer, and, secondly, on account of the winds, especially the mistral.

Of other diseases said to receive benefit here, there are mentioned various bronchial affections, liver complaints, Bright's disease, diabetes, asthma, heart disease, rheumatism, gout, and the feeble condition of delicate children. This resort is also suitable for that large class of the feeble from age or other cause who sustain life with less effort in any mild, sunny climate like this; and, finally, for that class who temporarily are worn out with all the demands of city life, who desire a change, *per se*, and who prefer a place where they can lead a simple life out of doors under sunny skies and in pure air, and devote themselves to rest, and freedom from exacting business or social duties. *Edward O. Otis.*

HYGROMA.—The term "hygroma" has been applied to a variety of conditions involving cyst-like spaces filled with fluid. Thus, widely different processes have been classified under the same head. It seems desirable to abandon the use of the word and to apply to the various conditions names more suggestive of their pathology. An increase in the amount of fluid in a tendon sheath leads to the formation of a cyst sometimes called hygroma. The term has been applied also to synovial bursæ distended with fluid.

Hygroma Congenitum Colli.—This term has been applied to a form of lymphangioma of the neck. The admirable description by König ("Lehrbuch d. speciellen Chirurgie," i., 528, 1893) has been largely drawn upon in the following account.

The tumor is present at birth. The surface is irregular and the tumor itself is lobulated. The lobules sometimes fluctuate, and at other times are very tense. The location is almost always in the submaxillary region. It may grow very rapidly and become very large. In this case it involves the entire anterior surface of the neck, extends to the face, and hangs over the clavicle and sternum upon the thoracic wall. Cystic lymphangiomata may also occur over the clavicle and on the dorsal surface of the neck. The ventral tumors may penetrate toward the pharynx, larynx, and œsophagus, and disturb the functions of these organs. The skin over the tumors is usually thin and may be even translucent. The growth is very prominent, and the portions lying directly over the great vessels may pulsate.

The functional disturbances in many cases are not marked; in others pressure upon the organs of the neck leads to dysphagia and dyspnœa and congestion of the vessels of the head. The patients may succumb to these symptoms, but this is not the rule. The prognosis is unfavorable, as the majority of the cases soon become cachectic and die. Operation usually hastens the fatal result.

The tumors occupy the subcutaneous and deep connective tissues, extending close to the vertebral column. They displace and may infiltrate organs, as do the malignant tumors. They are multilocular and consist of relatively thin connective-tissue walls which may be lined by endothelium. They are filled with a clear or yellowish liquid, which as a result of hemorrhage may become thick and chocolate-colored. The larger cysts are usually superficial; the smaller ones lie more deeply in the tissues, even at the base of the skull, in the mediastinum, and about the trachea and œsophagus.

In the tumors there occur spaces in the connective tissue of various forms which are not separated from the connective tissue by any special membrane. The larger spaces are rounded in form, or are divided into pockets by septa springing from the wall. They communicate with each other by larger or smaller openings.

It is probable that the spaces arise secondarily, because the smaller they are the more clearly defined are the communications. The smallest spaces consist of a system of vessels constricted at irregular intervals, or of a cavernous tissue whose lumina present an anastomosing system of channels. In either case the condition is continuous with a system of small anastomosing vessels, whose lumina are cylindrical or cleft-like, and have the characteristic distribution of lymph vessels. The spaces and channels are lined by endothelium.

The cystic spaces, then, consist of enlarged and distended lymph vessels. According to König this view is supported by Köster, von Winiwarter, Wegner, and others. It was formerly held by Rokitansky, Virchow, and Arnold that they originate from the connective tissue.

Perhaps most of the forms observed in adults originate in the same way. In these rare cases the tumor usually contains only a few cyst-like spaces and occurs near the trachea or in the region of the clavicle. It is possible that some of them originate from aberrant thyroids.

It seems desirable to abandon the name "hygroma" for this condition, and to use instead, "lymphangioma," a term more suggestive of its pathology.

H. S. Steensland.

HYGROPHILA.—The herb, also the seeds, of *H. spinosa* T. And. (fam. *Acanthaceæ*), an annual or biennial plant of India, very largely used medicinally by the natives. The herb contains a crystallizable body which is probably alkaloidal; the seeds; considerable gum; and much fixed oil, with indications of an alkaloid (*Hooper*). The drug acts as a diuretic and has been sparingly used as such in British practice. It has also been marketed as an adulterant of chiretta. *Henry H. Rusby.*

HYOID BONE, FRACTURES AND DISLOCATIONS OF.—Of the few cases on record of fracture of the hyoid bone, three were produced by hanging; three by the throat having been seized between the thumb and fingers; three by direct blows or falls upon the front of the neck; and one by muscular action alone.

In those cases in which the injury was produced by hanging, the body of the bone was broken. In all of the other examples the fracture involved one of the great cornua, or occurred at the junction of the cornua with the body. Crepitus is generally absent. In two of the recorded instances the adjacent mucous membrane of the pharynx was ruptured.

The symptoms observed have been a sudden sensation as if a bone had been broken; in a few instances a profuse bleeding from the fauces; difficulty in opening the mouth; in some cases dysphagia and aphonia; pain in movements of the tongue, with, usually, more or less swelling about the neck, and ecchymosis; later, cough, expectoration, and hoarseness. The circumstances which indicate with certainty the nature of the accident are unnatural mobility of the fragments, with or without crepitus, and an angular inward projection, which may generally be felt in a careful examination of the pharynx. The accident can be regarded as dangerous only in view of its complications. Of three cases in which it resulted from a direct blow only one survived, while of three resulting from lateral pressure upon the cornua all recovered.

The amount of difficulty in replacing the fragments of the bone will depend largely upon the extent of displacement and the consequent laceration of the neighboring tissues. An attempt should be made to accomplish replacement by introducing one finger into the mouth, while, with the opposite hand, the fragments are supported from without. From the nature of the parts, any attempt at the application of a splint or support will be useless.

Rest to the parts, together with general measures to allay inflammation, will generally constitute the available treatment.

Luxation of the hyoid bone is a very rare accident. The principal symptoms noted have been pain at the seat of injury and difficulty in swallowing. In a case observed by Daly (*Archives of Laryngology*, vol. i., p. 162) luxation of the left cornu had been of frequent occurrence, caused usually by laughing or yawning. A laryngoscopic examination showed no internal lesion. Reduction was effected by grasping the throat firmly with the thumb and index finger of one hand, steadying the head with the other hand, and then directing the patient to swallow vigorously, while at the same moment the parts were compressed between the thumb and finger, and then quickly released again. After the third effort the patient suddenly declared that he was relieved, and, in proof of this, he moved his head rapidly in all directions with ease and comfort, and drank successfully a glass of water.

D. Bryson Delavan.

HYOSCINE, SCOPOLAMINE.—($C_{17}H_{21}NO_4$.) An alkaloid obtained from henbane and scopola, and existing in other Solanaceæ. It occurs as a thick, colorless syrup, soluble in alcohol, only slightly in water, but all its salts form in large, white, prismatic crystals, freely soluble in water, insoluble in alcohol and ether. The salts also resemble each other in therapeutic as well as physical properties. The hydrobromate, hydrochlorate, sulphate, and hydriodate are prepared, and the first-named is official.

As a mydriatic, it is rapid, energetic, and brief, but its action is readily maintained. During the administration of the drug its effect on the pupil is an early symptom. Dilatation is said to be more marked with a one-fourth to one-half-per-cent. solution than with a one-per-cent. solution of atropine; it has to be used with caution on account of the readiness with which the system is affected. In this direction, therefore, it is to be classed with atropine. For its effects upon the peripheral nervous system, and upon the secretions, the action of atropine may also be consulted. Centrally, however, its action is very different. The stimulant action so characteristic of atropine is here present, if at all, only as a very brief primary stage, and is followed by sedation, or depression, which constitutes the characteristic action of the drug. In very sensitive subjects the period of excitement may be prolonged, but usually it constitutes the slightest preliminary stage, and is followed by drowsiness, and if the dose be full, by a natural sleep. The spinal centres are similarly depressed, especially the reflexes. Depression of the sensory centres is very mild and does not materially affect painful conditions. Circulation and respiration are both reduced, though the pulse rate is increased.

Its toxic action is shown by the dilated pupil, rapid pulse, relaxed arteries and redness of the surface, dry, hot skin, rapid breathing, and coma and convulsions. Therapeutically, hyoscine has come into prominence as a sedative and hypnotic. It has largely supplanted morphine in the treatment of acute mania and delirium tremens, in restlessness, in the violent manifestations observed in all forms of mental disorders, and in hysteria and epilepsy. Its sedative action is very rapidly produced, and in the majority of cases a calm and refreshing sleep ensues. From this sleep the subject can be readily and completely roused. When pain is the cause of insomnia, the remedy is not of much service. Its action is purely calmative and sedative on the brain, and it should not be administered as a powerful or decided hypnotic. In insomnia it is applicable only in cases in which this arises from central or nervous excitement. In mania, and when there is much excitement, it should be given in full doses of gr. $\frac{1}{60}$ by the mouth, or gr. $\frac{1}{120}$ to $\frac{1}{100}$ hypodermically; a small dose is generally sufficient. When the symptoms are less acute, smaller doses should be given.

Hyoscine has also proved itself very efficient in the treatment of chronic mania and all nervous affections accompanied by mental restlessness; also in nervous diseases characterized by debility and tremors, as in paralysis agitans, disseminated sclerosis, and chronic alcoholism. In these cases the stimulating action of small doses is taken advantage of, and gr. $\frac{1}{200}$ daily or twice a day is a sufficient dose. Its antispasmodic action is also secured with the same small dose, and it may be used, and with benefit, in chorea, asthma, and other spasmodic troubles of a nervous origin. The system readily becomes accustomed to it, and calls for increasing doses. When cardiac disease is present the use of hyoscine should be avoided or it should be given with great caution, on account of its depressing action on the heart and circulation.

The early physiological effects of the drug are manifested far in advance of dangerous symptoms, but in some cases very severe toxic symptoms have been produced by doses of gr. $\frac{1}{20}$ and $\frac{1}{10}$. Pilocarpine and morphine are physiological antidotes. The former has proved very serviceable and may be administered freely, as much as two grains having been required in a case of delirium tremens in which a comatose condition followed frequent doses of hyoscine.

Henry H. Rusby.

HYOSCYAMINE, HYOSCYAMINA. — ($C_{17}H_{23}NO_3$.) An alkaloid obtained from henbane and also existing in other species of *Hyoscyamus*, and in belladonna, stramonium, and other *Solanaceæ*. Professor Ladenburg demonstrated that atropine, daturine, and duboisine are identical with hyoscyamine, both in chemical constitution and in physiological action. Any difference is to be found in the molecular arrangement of the constituents, and not in any fundamental change. The terms "atropine" and "hyoscyamine" have been applied to the heavy and light mydriatic alkaloids obtained from the belladonna and henbane plants, the former being the heavy and the latter the light alkaloid. It is now known that both the heavy and the light alkaloids may be obtained from either plant, according to the process of manufacture. The light may be converted into the heavy by melting under reduced pressure, by the addition of caustic soda to its alcoholic solution, and in other ways.

Hyoscyamine occurs in light, silky, snow-white crystals, without odor, soluble in one hundred and twenty parts of water, freely soluble in alcohol, and in acidulated water. There is also an uncrystallized or amorphous hyoscyamine, of a dark-brown extract-like mass, with a strong disagreeable odor. This appears to be a mixture of the various alkaloids and extractive matters. A sulphate, hydrochlorate, hydrobromate, and hydriodate of hyoscyamine are prepared, the first and third of which are official; they are alike in degree of strength and character, forming white, fine crystals very soluble in water. A sulphate and hydrobromate prepared from the amorphous alkaloid are amorphous, deliquescent salts, and less active and certain in their effects.

The therapeutic properties of hyoscyamine are very uncertain. At times it exactly resembles atropine, at others quite closely hyoscine. The cause of this variation is not determined, but it appears probable that it is due to the presence respectively of atropine and hyoscine in the commercial article, as such is the effect when these impurities are known to exist. The degree of activity is equally variable. It is normally weaker than both atropine and hyoscine, and is often so weak as to require doses which would be dangerous in the case of either of those alkaloids. On the other hand, alarmingly poisonous symptoms sometimes follow the ordinary dosage, which is larger than that of the others. The presence of the amorphous salts in the market is the source of much of the uncertainty of its action, and the cause of many of the toxic symptoms. The dose of these salts is usually much larger, being from gr. $\frac{1}{8}$ to i., but they should never be employed. Even the "pure" alkaloid of Merck is given in one-quarter-grain doses, while his "chemically pure" alkaloid must not be given in excess of gr. $\frac{1}{50}$.

The mydriatic action of hyoscyamine is rapid and powerful, but not so manageable as that of atropine. Cases are reported in which it produced spasms of the ciliary muscle and intense pain and distress; the solution used was gr. $\frac{1}{4}$ to the drachm, and relief was obtained by placing in the eye a stronger solution of the same alkaloid. The toxic effects produced are the same as those of hyoscine, viz., dryness of the throat and mouth, and of the skin, accelerated pulse, dilated vessels, and excitement followed by convulsions and coma.

This alkaloid is employed as an hypnotic, nerve sedative, and antispasmodic, in mania, restlessness, delirium, insomnia, and all conditions accompanied by mental excitement; also in asthma, chorea, epilepsy, etc.

Henry H. Rusby.

HYOSCYAMUS. See *Henbane.*

HYPERIDROSIS is a functional disorder of the sweat apparatus accompanied by a more or less excessive increase of the normal amount of sweat excreted. This increase may be local or general. Local forms are symmetrically confined to certain regions such as the palms of the hands, soles of the feet, axillæ, or genital regions. Cases of unilateral excessive sweating, confined to one side of the body wholly, have been observed, but they are rare; of more frequent occurrence, although still not common, are the cases of unilateral sweating limited to one side of the head or to one limb. Usually intermittent, the sweating in some cases may be continuous and is aggravated by hot weather, emotion, depression of general health, etc.; and the disturbance may be temporary or permanent, depending upon its exciting cause. Subjects of the disorder are nearly always in a lowered state of health, sometimes hysterical and often nervous. The direct causes which lead to local hyperidrosis are quite undetermined. Examinations of sections from the palms of the hand fail to show any abnormal features of either the glands or the epithelium. The disorder is to be regarded as purely functional, connected with a disturbance of the vaso-motor control, no doubt, but as yet the exact links of the chain have not been definitely placed.

In the *treatment* of hyperidrosis, whether local or general, the condition of the patient's general health is of prime importance; the various ferruginous tonics, mineral acids, arsenic, strychnine, and quinine, are all of value. Belladonna and atropine, though but of temporary benefit, are of service at the outset of treatment in most cases. Cold baths for general toning of the circulation are strongly recommended. External treatment must be resorted to and is often very efficacious. In the local form that attacks the hands much benefit will be derived from immersing the palms for a few moments only in water as hot as can be borne, dabbing dry with a soft cloth, and then dusting on boric acid powder. The same treatment for the soles of the feet may be employed. A saturated alcoholic solution of boric acid dabbed on the palms during the day will control very well the excessive sweating of the hands that is so annoying to those who do much writing. Hebra's treatment for hyperidrosis of the feet consists of enveloping the feet, the toes separately, after thorough washing and drying, in strips of cotton cloth, over which is spread, to the thickness of a knife blade, his Unguentum diachyli. The parts are well bandaged and the patient may subsequently either remain at rest or pursue his vocation, wearing shoes and stockings that have not been previously used. In twenty-four hours the feet are redressed without washing, after dry rubbing and a dusting powder. This process is repeated daily for from ten to twenty days, after which a dusting powder, preferably boric acid, may be substituted for the local dressing. There occurs a parchment-like desquamation of the skin in thick, yellowish-brown flakes, beneath which is formed a new and at first tender, but apparently normal, epidermis. When the latter has lost its tenderness, the feet are for the first time washed with water. The process is to be repeated in case of failure.

Prognosis in any case of hyperidrosis is uncertain. At times treatment may meet with brilliant success; again, it is followed by complete failure. The disorder may disappear spontaneously, only to recur and prove obstinate to all measures. *Charles Townshend Dade.*

HYPERMETROPIA—H—(from ὑπέρμετρος, overmeasure, and ὤψ, eye—less correctly hyperopia; *Uebersichtigkeit*, Ruete, 1853; incorrectly *hyperpresbyopia*, Stellwag, 1855) is the name given by Donders (1860) to the abnormal refractive condition of the eye in which its principal focus—*i.e.*, its focus for parallel or practically parallel rays, such as are received from a distant object—lies at some point beyond the actual position of the retina. In H the antero-posterior axis of the eyeball is too short relatively to the focal length of the eye as determined by the radii of curvature of its three refracting surfaces, namely, the anterior surface of the cornea and the anterior and posterior surfaces of the crystalline lens, and in typical H the axis is actually shorter than in the normal or emmetropic eye. H is ordinarily an inherited condition, and may then be regarded as a result of incomplete development of the great posterior segment of the eyeball, in consequence of which the axis remains shorter than in the normal eye.*

The essential points of difference between the emmetropic and the hypermetropic eye are shown in Fig. 2758, in which the dotted outline represents in section the normal or emmetropic eye, and the continuous outline a hypermetropic eye. It is a property of the emmetropic eye, when in a state of accommodative rest (see *Accommodation and Refraction*), that the sum of the refractions at the surface of the cornea and at the two surfaces of the crystalline lens is just sufficient to unite all the rays of a parallel pencil, *A, E, B,* in a focus upon the retina at *E.* When the retina is so misplaced as to lie within the principal focus of the dioptric media, the pencil is cut by the retina before its rays have come together, and the image of a distant point upon which the eye is directed is formed at *H* as a circular spot of appreciable diameter (circle of confusion). What is true of a pencil of rays emanating from one point of the distant object is true of pencils emanating from other points of the same object; the inverted retinal image is, therefore, more or less confused, and all the finer details of the object are lost. This confusion of distant vision is experienced by every hypermetrope whenever his accommodation is fully relaxed, and it may be evoked artificially, in any case of H, by paralyzing the accommodation by instilling a drop or two of a mydriatic solution, such as atropine, into the conjunctival sac.

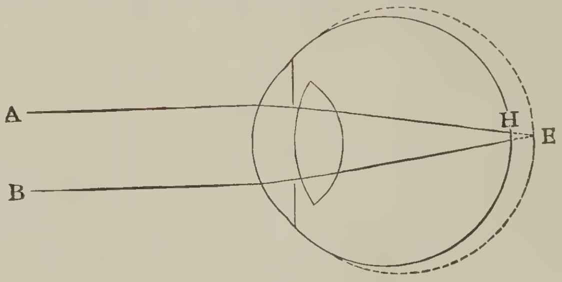

FIG. 2758.

As the emmetropic eye, when in a state of complete accommodative relaxation, is adjusted for the focussing of parallel rays upon its retina, so the hypermetropic eye is adapted for the focussing of rays of some definite degree of convergence. Fig. 2759 shows a convergent pencil, *A′, H, B′*, focussed upon the retina of the hypermetropic eye at *H*, and also a pencil, *A, H, B*, of rays originally parallel, but rendered convergent by passing

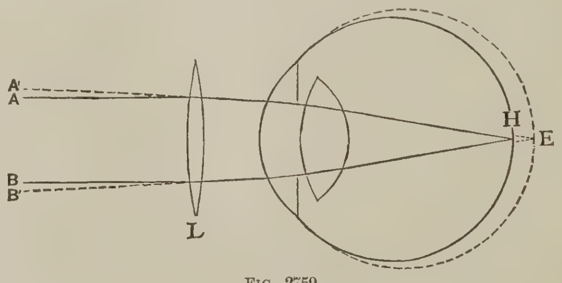

FIG. 2759.

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* H is, in fact, the normal condition in the Quadrumana, and in the higher Mammalia generally.

through a convex lens, *L*. The hypermetropic eye receiving and focussing such a convergent pencil becomes practically equivalent to an emmetropic eye receiving and focussing a pencil of parallel rays, and as any required degree of convergence may be given to an originally parallel pencil by allowing it to traverse a convex lens of suitable power, so the vision of a hypermetrope may always be perfectly corrected for distance by wearing properly chosen (neutralizing) convex glasses.

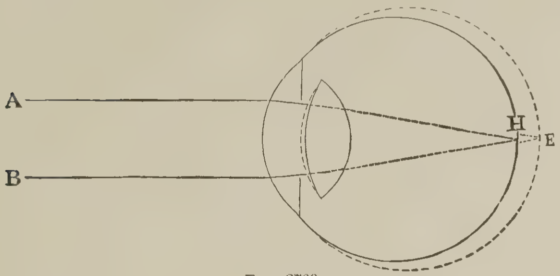

FIG. 2760.

H does not ordinarily give rise to defective vision at a distance so long as the range of accommodation (A) remains unimpaired, as in the case of young persons. The reason of this will appear from an inspection of Fig. 2760, which shows a hypermetropic eye adjusted for the focussing of a pencil of parallel rays, *A*, *H*, *B*, through the increase in the convexity of its crystalline lens incident to the act of accommodation. The focussing of the several pencils of rays which form the retinal image is here as perfect as in the case shown in Fig. 2759, but with the difference that some part of the accommodation is expended in advancing the focus from its normal position at *E* to the actual position of the retina at *H*, so that only the unexpended part is available for the further adjustment of the eye to meet the requirements of near vision.

Fig. 2761 shows a hypermetropic eye, in its condition of fullest accommodative adjustment, focussing a divergent pencil, *A*, *H*, *B*, emanating from an object situated at its nearest point of distinct vision. Fig. 2762 similarly shows an emmetropic eye focussing a more divergent pencil, *A*, *E*, *B*, emanating from a nearer object situated at its nearest point of distinct vision. Comparing these two figures, it will be seen that the near-point of distinct vision for the hypermetropic eye lies farther from the eye than the near-point of distinct vision for the emmetropic eye, so that the hypermetropic eye, as compared with the emmetropic eye, is limited in its region of adjustment for near vision (region of accommodation), and the higher the grade of H the greater the limitation.

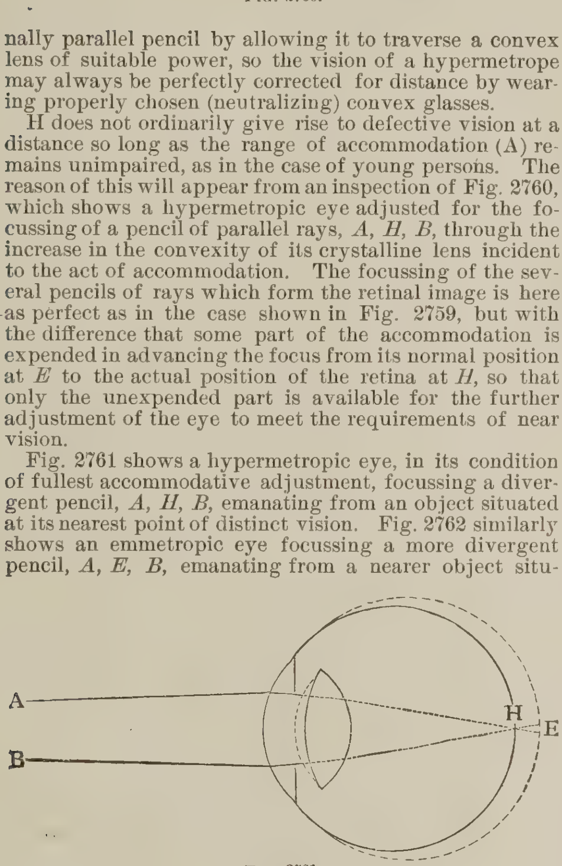

FIG. 2761.

In very high grades of H the absolute range of accommodation (A) may be insufficient, even in young persons, for the perfect focussing of parallel rays upon the retina, in which case H is said to be absolute (H *absoluta*). This condition is shown in Fig. 2763, in which the focus of the parallel pencil, *A*, *H*, *B*, which, without aid from the accommodation, would lie at *E*, is, through the full exercise of the accommodation, advanced to *H*, which, however, still lies behind the actual position of the retina at *Ha*. A point in the distant object, which in the emmetropic eye would be depicted as a point at *E*, is, therefore, actually depicted as a circular spot (circle of confusion) at *Ha*. Even under the full exercise of the accommodation this circle of confusion still remains a spot of appreciable diameter; the retinal image of the distant object is therefore made up of circles of confusion instead of points, and, although it may be improved in definition through the exercise of the accommodation, the picture remains confused in its details.

This distinction, in young persons, between H *absoluta* (H > A) and the lesser grades of H (H < A) is important. In H < A the hypermetrope is able to see at a distance by using only a part of his accommodation, and he has still a residual accommodative power sufficient to meet, in some measure, the requirements of near vision. He therefore forms the habit of using some part of his accommodation in every act of vision, and by a strong exercise of the same faculty he may even be able to read, although necessarily at the cost of excessive effort, and generally for a limited time only. Hence a hypermetropic child is apt to be judged harshly by parents or teachers, who, recognizing the fact that he is able to apply himself effectively to his books for a short time, are slow to comprehend that he becomes quickly wearied and is incapable of sustained application (see *Asthenopia*). In certain cases, however, impelled by the strong desire to see distinctly, the child learns to force his accommodation by concentrating an abnormally powerful impulse upon the two correlated functions of accommodation and convergence, and thus acquires the power of sustained application by sacrificing binocular vision and laying the foundation of a convergent squint. (See *Asthenopia* and *Strabismus*, also later in this article.) In H > A (H *absoluta*), on the other hand, distinct vision is impossible even at a distance, and, although the definition of objects may be considerably improved by a strong accommodative effort, it nevertheless falls so far short of perfect vision as not to offer a sufficient motive for continuous or prolonged exertion. In H *absoluta*, therefore, the case is apt to be regarded as one of defective vision, and glasses are perhaps tried at random until a pair of convex spectacles is found, which renders the use of the eyes comparatively easy. But even here prejudice may come in to deter a parent from permitting the child to

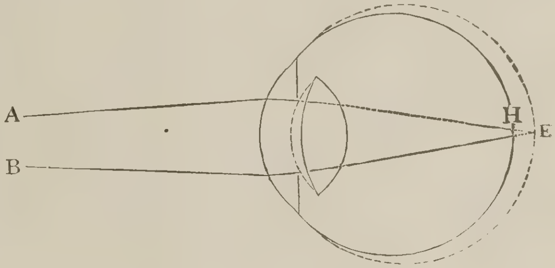

FIG. 2762.

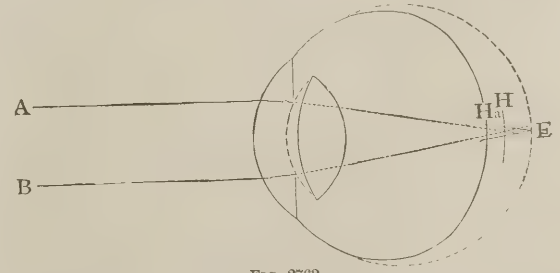

FIG. 2763.

wear spectacles "old enough for its grandfather," and efficient aid from glasses may be withheld.

H *absoluta* is but rarely met with in the first years of childhood, for the reason that at this early age the normal range of accommodation is very large; but often in youth, and still more in adult life, the progressive limitation of the range of accommodation comes into play to increase the disability of the hypermetrope, and, with advancing years, to render it complete. Thus all cases of $H < A$ pass sooner or later through the stage $H = A$ to $H > A$ (H *absoluta*), and the hypermetrope suffers in turn from disabilities incident to successive stages of his refractive anomaly, to find rest and distinct vision, perhaps after the lapse of many years, in convex glasses of which he should have had the benefit in childhood.

As the emmetrope at about the age of forty-five years has generally lost so much of his power of accommodation as to require aid from convex glasses to enable him to see distinctly at the usual reading distance of about one-third of a metre (twelve to fourteen inches), so the hypermetrope finds his near-point receding beyond this limit of distance at an earlier age dependent on the grade of H. Hence he will need convex glasses for reading, comparatively early in life, and will be compelled to change them from time to time for other glasses, which must always be of greater power than those which would suffice for an emmetrope of the same age. For the emmetrope the limit of power of the convex glasses required in old age for reading does not much exceed 5 dioptries; the hypermetrope, however, requires in old age reading-glasses of a power equal to $H + 5$ dioptries, which in an extreme case may amount to as much as $10 + 5 = 15$ dioptries, or even a little more, although generally much less than this. It will be observed that the limit of aid required by the hypermetrope is expressed by the sum of two quantities which are themselves limited, thus meeting the objection not infrequently urged by venders of spectacles, that a time will come when no glasses can be found of sufficient strength to admit of reading. In fact, the power of the convex glass which fully corrects the refractive deficiency in childhood will never require to be increased by more than four or, at most, six or eight dioptries to meet the further disability incident to loss of accommodation, to the diminution of the refractive power of the crystalline lens in old age, and to senile deterioration of the acuteness of vision. (See *Presbyopia;* also H *acquisita,* later in this article.)

We have seen (*vid.* Fig. 2760) that a hypermetrope who sees distinctly at a distance necessarily makes use of some part of his accommodation, and that he is compelled to accommodate in excess of the normal degree in order to see nearer objects distinctly. He thus forms the habit of associating some degree of accommodation with the act of directing the eyes upon any distant object, and he generally continues to accommodate to some extent even when he is made to look through neutralizing convex glasses. Hence it may happen that a hypermetrope will reject as incompatible with distinct distant vision not only such convex glasses as completely correct his refractive defect but even notably weaker convex glasses, and, in exceptional cases, this habitual tension of accommodation may be so great as even to simulate myopia. In such a case the grave mistake may be made of having recourse to concave glasses to correct a supposed but non-existent myopia, and so materially aggravating the actual disability.

We have, therefore, to recognize a hidden or latent H (H *latens*—Hl), which eludes discovery by the ordinary subjective tests made with convex glasses, and also a manifest H (H *manifesta*—Hm), which is readily detected and measured by this mode of examination. Thus we may have to do with a case of apparent emmetropia, or possibly even of apparent myopia, which, on thoroughly paralyzing the accommodation by atropine, turns out to be really a case of H; and in every case of H in a young person with normal accommodation we obtain, by tests with convex glasses alone, a measurement which falls notably short of the total refractive defect (H *totalis*—Ht) as measured by means of convex glasses after artificial paralysis of the accommodation.

Hl is then the expression of the degree of accommodative tension which persists during the fixation of a distant object, and the ratio which it bears to Hm is dependent upon the extent of the range of accommodation. Hence it is greatest in childhood, and it diminishes year by year throughout youth and adult life until, at the age of sixty, or perhaps somewhat earlier, it becomes wholly merged in Hm, which then becomes equal to Ht. $Hm = Ht$ is also realized as a pathological condition as a result of paralysis of the third (motor communis) nerve, or of its terminal branches, and it is produced artificially by the instillation of atropine or other sufficiently powerful mydriatic drug. It is also generally true that the hypermetrope relaxes his accommodation almost completely when the eyes are not in use, so that it is practicable, in a large proportion of cases, to measure Ht objectively by means of the ophthalmoscope, either by the direct method of examination or by employing the shadow test (see *Shadow Test*). More frequently, however, we first measure Hm subjectively, by successive trials with convex glasses, until we have fixed upon the strongest glass through which a test-object, such as the appropriate selection from the test-letters of Snellen, is seen distinctly at a distance of five or six metres, and then measure Ht by the use of the same test-letters at the same distance, after having fully paralyzed the accommodation by means of atropine or of hyoscyamine; we then calculate Hl by means of the equation, $Hl = Ht - Hm$.*

We have thus far considered H in its relations to A mainly as if it were a question of vision with a single eye; as a fact, however, we see with the two eyes at one and the same time, so that every act of binocular vision involves two simultaneous adjustments—namely, accommodation for some particular distance, and convergence of the axes of the two eyes upon the object for which they are severally accommodated. In emmetropia these two adjustments go hand-in-hand, so that parallelism of the visual axes is associated with complete relaxation of the accommodation, and convergence upon any near object is associated with accommodation for the same distance; or, taking as units of measurement the degree of accommodation required for distinct vision at the distance of one metre (1 dioptrie), and the degree of convergence necessary for single vision at the same distance of one metre (1 metre-angle), we find in emmetropia n units of accommodation (n dioptries) always associated with n units of convergence (n metre-angles). In ametropia this harmony of relation is essentially disturbed, for with convergence equal to n metre-angles the corresponding accommodation of n dioptries is either too great (in M) or too little (in H) for distinct vision at the distance of the point of intersection of the visual axes. Confining our attention to the conditions as they exist in H, we find that with convergence of n metre-angles the accommodation necessary for distinct vision amounts to $n + H$ dioptries; or, inverting the form of the statement, with accommodation of n dioptries, the convergence necessary for single vision is only $n - H$ metre-angles; in other words, any given degree of convergence calls for a relatively strong effort at accommodation to meet the requirements of distinct vision, and, *vice versa,* the degree of accommodation required for distinct vision must be associated with a relatively weak effort at convergence in order to admit of single vision with the two eyes.

The maximum of accommodation (*absolute* A) is attained only when the convergence is simultaneously exerted to the utmost, and even in emmetropia this involves a very strong crossing of one of the eyes. In H, however, excessive convergence is the rule in every act of accommodation whenever the conditions are such as not to admit of binocular vision, and *absolute* A is attained only in conjunction with even stronger crossing than in emmetropia.

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* As a rule, Hl is less than Ht, and the latter is the arithmetical sum of Hl and Hm, but in the exceptional cases in which H simulates emmetropia $Hm = 0$: in the still rarer cases in which an apparent myopia gives place to H after artificial paralysis of the accommodation, Hm appears as a negative quantity, and Hl is greater than Ht.

H *absoluta* includes, therefore, only those cases in which, even under the condition of extreme crossing of one of the eyes, the accommodation is insufficient for distinct vision at a distance.

In convergence for any given distance the associated accommodation is found by experiment to be always less than when the convergence is for some shorter distance; in other words, every act of convergence not only compels an approximately proportional exercise of the accommodation, but inhibits, within certain limits, its greater exercise. Hence, in binocular vision, the *relative* A (A_1, *i.e.*, the range of accommodation as related to the convergence) is always less than the *absolute* A; we have, therefore, to recognize a type of H in which the *absolute* A is sufficient for distinct uniocular vision at an infinite or at some finite distance, but in which the *relative* A is insufficient for perfect binocular vision at any distance (H *relativa*).

In H *relativa* perfect uniocular vision is possible, not only for distant, but in most cases also for near objects, but only on the condition of crossing the non-participating eye.

It has been stated elsewhere that the link by which the accommodation and the convergence are tied together is not an absolutely rigid one. This is proved by the fact that, as a rule, perfect binocular vision is still possible when moderately strong concave or convex glasses, or convergent or divergent prisms, are placed before the two eyes. In the former case the convergence remains unchanged notwithstanding the altered accommodation, and in the latter case the accommodation remains unchanged notwithstanding the altered convergence; but to these adjustments of the convergence to varying states of the accommodation, and of the accommodation to varying states of the convergence, there is a limit well defined in each case, but differing in different cases. This binocular range of accommodation (A_2) may undergo considerable modification, according as it is habitually exercised in a negative or in a positive sense, and the ability to relax the binocular accommodation in M, or to force it in H, is usually considerably greater than in emmetropia, thus conserving in a measure the harmony of the two adjustments. Confining our attention to the conditions as they exist in H, we find that in moderate grades of H, with ample range of accommodation, it is often perfectly easy to accommodate accurately for a distance without convergence of the visual axes, and in many cases, at least in childhood and youth, also to accommodate and converge correctly for the ordinary reading distance, without conscious fatigue.

This type of H, in which binocular vision is perfect for a distance, and in which it may be also possible to read easily with the two eyes, is called H *facultativa.*[*]

As the power of convergence remains practically constant throughout life, while the range of accommodation diminishes progressively through the periods of youth and maturity until it is reduced to zero in old age, it follows that H *facultativa* is but an early, and often a quickly passing stage in the life-history of most hypermetropes, changing sooner or later to H *relativa*, and ultimately to H *absoluta;* nevertheless, the duration of each of these earlier stages is not infrequently measured by years, and may then afford abundant time to develop the characteristic disabilities and to work out the special tendencies to mischief incident to each type.

These disabilities and tendencies must now be considered in detail.

(*a*) In H *facultativa* binocular vision is perfect at a distance without glasses, and also with convex glasses of any power up to that which measures the manifest hypermetropia. In the case of many young hypermetropes, convergence for some short distance is also associated with good accommodation for the same distance, so that it may be possible to use the eyes easily in near work. In other words, the sphere of the habitual exercise of the accommodation (region of accommodation) has become so adjusted to the abnormal condition of refraction as to allow the two correlated functions of convergence and accommodation to work harmoniously together. This compensatory displacement of the region of accommodation is sometimes so perfect, in childhood and youth, that, even with Ht = 3 or 4 dioptries, the prolonged use of the eyes in reading or other close work may be unattended with fatigue, and in many other cases the available binocular accommodation proves equal to all ordinary demands upon it. A young hypermetrope may thus remain for years in complete unconsciousness of his defect, but sooner or later, as a consequence of the progressive physiological limitation of A, or perhaps of a temporary impairment of this function incident to some transient illness, or in connection with the change to a new vocation which calls for an unwonted exercise of the accommodation, he finds that his eyes are no longer equal to the demands made upon them. The inability to use the eyes continuously in near work may be first discovered in connection with the increased requirements of the higher grades in school, or the assiduous employment of the eyes in fine sewing. In other cases the disability manifests itself in early childhood, as when the eyes are first exercised in the more delicate tasks of the kindergarten, or in beginning the study of geography from maps crowded with names engraved in minute letters. Small near objects are, perhaps, still seen clearly for a little while, and apparently without great effort, but the accommodation soon becomes fatigued, and fine print then appears blurred, or may become altogether illegible. Under the strong stimulus of emulation, or dread of censure, the child may perhaps persevere in his efforts, though at the cost of physical and mental strain and with increasing sense of fatigue, until at length he is compelled to desist. After a short rest he may be able to resume his work, but only for a shorter time than before, and he soon finds himself unable to read at all. Thus the familiar picture of accommodative asthenopia is developed, to give place, sooner or later, to inability to see distinctly at the distance of the point of intersection of the visual axes (see *Asthenopia*).

(*b*) H *relativa*, by its definition, implies a state of conflict between the convergence and the accommodation at all distances. Either the two eyes are habitually directed upon the object, in which case the lagging accommodation is insufficient for the perfect focussing of the retinal images, or the accommodation asserts itself in a strong effort to see clearly with a single eye, and the axis of the fellow-eye assumes a crossed direction. The conflicting impulses on the one hand to focus perfectly for the distance of the object, in order to see it distinctly, and on the other hand to direct the two eyes accurately upon it, in order to avoid seeing it doubled, thus contend for the mastery until at length one of two alternative conditions is established—namely, distinct vision with a single eye, the other eye assuming a crossed direction (periodic or confirmed convergent strabismus), or single vision with the two eyes, but with insufficient accommodation and consequent imperfect recognition of the finer details of the object.

Any condition which detracts from the perfection of binocular vision may predispose to the development of convergent strabismus in the presence of H. Prominent among such conditions is an original or acquired imperfection of one of the eyes. Thus an imperfect eye is easily thrown out of use whenever the vision of the fellow-eye may be materially improved by so doing. In fact, we find that in by far the greater number of cases of strabismus the crossed eye is decidedly inferior to its fellow in visual acuteness, even though no structural defect is to be detected. Again, any pathological condition of one eye, attended with temporary or permanent impairment of its visual acuteness, may so detract from the importance of the part which it plays in binocular vision as to allow it to be easily excluded from participation in the act of vision. Under this category fall cases of strabismus, dating from the appearance of a corneal phlyctenula, or following the formation of a corneal scar. Again, it would appear that the faculty of perfectly controlling the convergence to meet the requirements of binocular vision is often more tardily acquired than that of perfect accommodation, so that a hypermetropic child with normal acuteness of vision in both eyes may acquire the habit of crossing one eye in order to see clearly with the other before he has become confirmed in the habit of using the two eyes together. In such cases the crossing is apt to alternate between the two eyes (strabismus alternans), and this alternation may either persist for years or may give place to the more common condition of habitual crossing of one and the same eye. A difference in the grade of H in the two eyes is often sufficient to determine the crossing of the more hypermetropic eye, and this in some cases even when this eye is in other respects somewhat the better eye.

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[*] Donders, who made the first thorough study of hypermetropia, writing for English readers ("Anomalies of Accommodation and Refraction of the Eye," London, 1864), gave the name *facultative* H to this condition. In its French and Italian forms this word has a well-recognized meaning, and from these languages it has been adopted in German. In English it can hardly be said to be fully naturalized. Its meaning, as given in the "Dictionnaire de l'Académie," is "Qui laisse la faculté de faire ou de ne pas faire une chose; dont on peut, à son gré, faire ou ne pas faire usage." The writer of this article ventured, in the first edition of this HANDBOOK, to adopt a Latinized form of the word, with a view to more perfect uniformity of notation.

(c) H *absoluta*, the ultimate stage to which every case of H necessarily tends, has been already defined as a condition in which distinct vision is impossible, even under a maximum exercise of the accommodation conjoined with the strongest convergence. With the development of this absolute disability, the hypermetrope learns to desist from unavailing efforts at accommodation, and so finds relief from his asthenopia in enforced amblyopic vision. If in the previous stage of H *relativa* the excessive convergence has been limited to the times of actual exercise of the accommodation (periodic strabismus), now that no effort suffices for distinct vision, he learns, with the cessation of all attempts at accommodation, to abandon also the habit of crossing the eyes. Very pronounced strabismus may thus become decidedly less pronounced, or may possibly even disappear.

Paresis of accommodation, from impairment of the function of the ciliary nerves, is attended, even in emmetropia, by many of the characteristic symptoms of H; and when it occurs in a hypermetropic subject it may develop special conditions, which may be temporary or permanent according to the nature of the cause which underlies the paresis. Thus, in connection with the temporary paresis of accommodation not infrequently observed as a sequel of diphtheria, H *facultativa* is converted, at least for the time being, into H *relativa* or H *absoluta*, and H *relativa* into a higher grade of the same or into H *absoluta*. If the change is limited to the state of H *relativa*, vision becomes indistinct, or, more rarely, a true convergent strabismus appears, which may even develop later into permanent squint. Complete paralysis of accommodation, or paresis occurring in connection with a very high grade of H, develops, on the other hand, the condition of H *absoluta* with attendant indistinctness of vision at all distances and immunity from all tendency to crossing of the eyes.

Artificial paresis or paralysis of accommodation, evoked by the instillation of a mydriatic solution into the conjunctival sac, may play an important part, in the presence of H, by transforming H *facultativa* into H *relativa* or H *absoluta*, or H *relativa* into H *absoluta*, thus promoting in some cases and suppressing in other cases a preexisting tendency to strabismus. As a rule, incomplete mydriasis, when limited in its effect to the production and maintenance of the condition of H *relativa*, favors the development of strabismus, and may even evoke it in a case of H *facultativa* which might otherwise have passed gradually through the stage of H *relativa* to H *absoluta* without other symptoms than those of accommodative asthenopia with ultimate inability to see distinctly except by the aid of convex glasses. On the other hand, a condition of complete mydriasis, if long enough maintained, may, by rendering all efforts at accommodation unavailing, lead also to the abandonment of excessive exercise of the convergence, and so permit binocular vision to reassert itself even in a case of already developed crossing.

Myotics work a change in the relation of the accommodation to the convergence exactly the opposite of that produced by mydriatics. Under the influence of eserine, or of pilocarpine, H *absoluta* may be transformed, for the time being, into H *relativa*, or H *relativa* into H *facultativa*, or even into temporary emmetropia or myopia. Unfortunately, however, for the general applicability of this method to the amelioration of the condition of young hypermetropes, the known myotics are essentially transient in their effect, so that it is always difficult, and often practically impossible, to maintain a uniform degree of myosis for any lengthened period. In low grades of H in young persons the systematic instillation of very small doses of pilocarpine is often of use by assisting the accommodation for a time, and may thus be a valuable adjuvant to other measures, such as carefully regulated daily exercise of the eyes, in dealing with asthenopia when dependent in part upon temporary weakening of the accommodation. In the higher grades of H, and especially in middle and advanced life, the sphere of usefulness of myotics is extremely limited.

It has been already stated that H is ordinarily an inherited defect, the result of incomplete development of the posterior segment of the eyeball. Myopia, on the other hand, is generally an acquired condition, resulting from a pathological distention of the eyeball. It follows that a similar pathological distention, when it occurs in the hypermetropic eye, must necessarily be attended with a corresponding lessening of the grade of H. At a certain stage in this progressive distention H may thus pass into the condition of emmetropia, though with a thinned and weakened eyeball especially prone to further yielding of its coats under the continued action of the distending force. That a change from H, through emmetropia, to myopia, is of not infrequent occurrence is proved by the fact that individual cases of H in young persons, when examined at intervals of several years, often show a progressive diminution in the grade of H, or even a transformation into emmetropia or myopia. The statistics of the refractive condition of the eyes of large numbers of school children, showing a progressive decrease in the proportion of cases of H and a corresponding increase in the proportion of cases of myopia in the higher as compared with the lower classes, also the occasional occurrence in hypermetropic, emmetropic, or slightly myopic eyes of pathological changes in the fundus, such as are ordinarily found in the higher grades of myopia, point unmistakably in the same direction. The disappearance of H through its transformation into a pathological emmetropia or myopia must, therefore, be recognized as a possible, though, in most cases, an undesirable, event, and this possibility should always be kept in mind in weighing the indications for and against operative intervention in the treatment of strabismus in young children.

A form of H dependent on a physiological increase in the focal length of the crystalline lens (H *acquisita*) is a frequent incident in advanced presbyopia. In old age the myopic eye becomes, from this cause, somewhat less myopic, low grades of myopia pass into emmetropia or through emmetropia into low grades of H, emmetropia is transformed into H, and H becomes appreciably increased in grade. Inasmuch as A has now become reduced to a comparatively unimportant quantity, acquired H is nearly always absolute, and so reveals itself as a true *hyperpresbyopia*, necessitating the use of convex reading glasses of a focal length somewhat shorter than the actual reading distance, and of weaker (neutralizing) convex glasses for perfect vision at a distance.

H *acquisita* may also occur as a result of flattening of the cornea from disease, in which case it is generally complicated by irregular, or sometimes by approximately regular astigmatism (H + Ah). In such cases the damaged eye not infrequently goes out of use, and, in the presence of H of the other eye, may become crossed. If, however, this eye happens to be the better eye, the very strong accommodative effort required for tolerably distinct vision may give rise to crossing of its fellow.

A pathological shortening of the focus of the crystalline lens is not infrequently observed in the incipient stage of cataract in old persons. H may thus pass into emmetropia, or through emmetropia into myopia, and emmetropia may be transformed into a grade of myopia sufficient to admit of reading without the aid of glasses. This seeming improvement, often called second sight, is however, only temporary, and is lost sooner or later in the progressive failure of vision incident to increasing loss of transparency of the crystalline lens.

The diagnosis of H turns on the fact that the hypermetropic eye, when in a state of accommodative rest, is able to focus only convergent rays upon its retina at or near the fovea centralis, and, conversely, that a pencil of rays given off by any point in the fundus at or near the fovea centralis must necessarily emerge from the eye as a divergent pencil (see Fig. 2764). The methods employed for the detection and measurement of H are either subjective, based upon the recognition by the patient of the strongest convex lens through which distant objects are seen with undiminished distinctness, or objective, based upon the recognition by the examiner of the degree of divergence of the efferent pencils emanating from the fundus. The subjective method is generally the more accurate, and is to be preferred whenever the patient has approximately normal acuteness of vision, together with sufficient intelligence and training to enable him accurately to define his perceptions. Objective methods are, on the other hand, invaluable in the case of young children, and also in the case of exceptionally stupid or illiterate persons of riper years. By the subjective method we first measure Hm by preliminary tests made without the use of a mydriatic and we may subsequently determine Ht by repeating the tests after having thoroughly paralyzed the accommodation by instillations of atropine or of hyoscyamine. By objective methods we obtain, in most cases, a pretty accurate measurement of Ht without having recourse to full artificial mydriasis, although it is often desirable, or even necessary, to dilate the pupil in order to secure a satisfactory view of the central portions of the fundus. Inasmuch as it is not ordinarily necessary to paralyze the accommodation, we may, with great advantage, avail ourselves of the rapid but transient mydriatic action of cocaine, which, besides sufficiently dilating the pupil for purposes of observation, has the additional effect, in many cases, of measurably controlling any existing nystagmus. A mixture of cocaine hydrochlorate with euphthalmin hydrochlorate, in a solution containing one per cent. of each, may also be used for obtaining transient dilatation of the pupil.

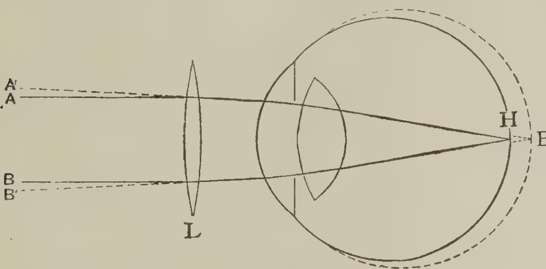

FIG. 2764.

In applying the subjective method we make use of a suitable test-object placed at the greatest convenient distance from the eye, usually the test-letters of Snellen hung upon the opposite wall of the room at a distance of say 5 metres, and direct the patient to read, with eyes well open, as many of the letters as he can. If vision is shown by this test to be of normal acuteness ($\frac{5}{5}$, or perhaps $\frac{5}{4}$), H *absoluta* and also myopia of any degree higher than 0.2 dioptrie are excluded; also any notable grade of astigmatism. H *facultativa*, or, under the condition of crossing of the visual axes, H *relativa*, may, however, be present. We next place a pair of weak convex trial glasses before the eyes, and again direct the patient to read as many of the test-letters as he can, using preferably another test-card with different letters. If through these glasses the acuteness of vision is still equal to $\frac{5}{5}$, we change the convex trial glasses for others of greater power, until we have hit upon the strongest convex glass through which the patient enjoys his maximum of visual acuteness. The value of this glass is the measure of Hm.* Having measured Hm, it is often possible to make a sufficiently accurate estimate of Ht by taking into account the degree of Hm and the age of the patient, but in other cases it is important to measure it directly. To this end we repeat the examination after having paralyzed the accommodation by the instillation of atropine or of hyoscyamine. Of these two agents the latter is the more powerful, and one or two instillations of a one-per-cent. solution are generally sufficient to produce full paralysis of accommodation in the course of an hour; if atropine is used it is generally advisable to repeat the instillation two or three times at intervals of half an hour, and to defer the examination for an hour or so longer. In many cases of H the accommodation yields more slowly to the relaxing influence of mydriatic agents, so that the full measure of Ht is obtained only after repeated instillations continued for at least twenty-four hours. Under the effective use of either of these mydriatics Hm and Hl become merged for the time in Ht, H *facultativa* and H *relativa* give place to H *absoluta*, certain cases of apparent emmetropia turn out to be actually cases of H *facultativa* in which H has been concealed by habitual tension of the accommodation, and a few cases of apparent myopia are shown to be really cases of emmetropia or of H, but simulating myopia through persistent accommodative tension.

The objective measurement of H is made with the aid of the ophthalmoscope by the direct method, using as points of observation the finest visible details of the fundus in the neighborhood of the fovea centralis. The best objects for this purpose are the smaller retinal vessels, which serve also for measuring any difference of refraction in the different ocular meridians (see *Astigmatism*), and the general texture of the fundus, which is usually distinctly granular. Under ophthalmoscopic examination, in a well-darkened room, the accommodation is generally found to be so far relaxed that the ophthalmoscopic measurement may be accepted as a very close approximation to Ht; the measure of Ht is then the strongest convex lens, placed behind the hole in the mirror, through which the details of the fundus are distinctly visible. This measure must, however, be corrected for the distance of the lens from the eye, and also for any ametropia which may be present in the eye of the observer.

Under full mydriasis an abnormally large area, both of the cornea and of the crystalline lens, is uncovered and brought into action in the formation of the retinal image, and it is not infrequently the case that, owing to a lower refractive power in the uncovered marginal zone, measurements obtained under atropine show a slight excess over Ht as it exists when the pupils are of normal diameter. It is therefore generally advisable, when glasses are to be given to correct the total hypermetropia, to prescribe them of a somewhat lower power than that indicated by tests made with dilated pupils.

The shadow test (retinoscopy, so-called; see *Shadow Test*) affords very accurate measurements. In common with the ophthalmoscopic observation of the fundus in the erect image, its results are wholly independent of the degree of vision which the patient may enjoy, and of the accuracy of his statements regarding his recognition of test-letters.

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* In strictness, 0.2 dioptrie should be subtracted from this measure, to allow for the finite distance of 5 metres at which the test-card is hung; and in the case of glasses of short focus a further correction must be made for the distance at which the lens is placed in front of the cornea, which is ordinarily about 15 mm. As most measurements of the refraction are made for the purpose of selecting glasses, this latter correction is generally superfluous.

For a description of additional devices which may be employed for the detection and measurement of hypermetropia, see *Optometry.*

The discovery of H is oftenest made through the recognition, by the patient, of an inability to use his eyes freely in near work, and if he happen further to discover that the reading glasses of some elderly person are of assistance to him, he may perhaps select for himself a pair of convex glasses sufficient for his present needs; and, having once experienced the aid afforded by these glasses in reading, he will be very likely, in replacing them, to choose glasses of greater power, until at length he arrives at an approximate correction of his Ht. In this self-treatment he will, however, be very likely to encounter opposition from the spectacle venders, owing to a still somewhat prevalent notion that convex glasses are injurious to the eyes of young persons, and that the stronger the glass the greater the injury. He is liable, therefore, either to be deterred from using glasses of the necessary strength, or to procure and wear such glasses as enable him to read with comfort, though under protest and in the dread of "wearing out his sight" through having recklessly forestalled the aid which he is told should be reserved exclusively for old age.

In early childhood H is seldom discovered except by the oculist, who is generally first consulted in consequence of some peculiarity in the manner of using the eyes, or because of the discovery of a tendency to strabismus. The child is noticed to scowl when looking intently at distant or near objects, or he is observed, in reading, to contract the opening of the eyelids, so as partially to cover the pupils, and at the same time to hold his book quite near to the eyes, in order to increase the size and intensity of the retinal images. In other cases he complains that he cannot distinguish the letters in his reading-book, or he miscalls certain words through imperfect recognition of individual letters. Possibly he tries on his mother's or grandmother's glasses, and, seeing much better through them, asks for them to aid him in his lessons, which he then learns more easily and with unwonted correctness. Not infrequently he learns to see distinctly with one eye by crossing the other whenever he is compelled to fix his attention closely upon any small object (periodic strabismus), and the family physician is perhaps consulted because the child is becoming cross-eyed. Of this suggestion he too often makes light, and puts off the parent by saying that "the eyes will probably come right of themselves," or that "the child is too young to be treated for cross-eye," or that "there is no help for cross-eye until it has become fully established, and then only by a surgical operation"; and so he advises waiting "until the child is old enough to decide for himself." "Teething," "indigestion," "worms," "mimicry" of a cross-eyed companion or nurse, "looking at the tip of the nose" or "at a lock of hair," and many other imaginary or, at most, only secondary causes are often invoked, with the result of encouraging mischievous delay through the neglect of the primary and essential factor in the case, namely, the hypermetropic conformation of the eyes. Unfortunately for the child, there is just enough of plausibility in some of these suggestions to lead a physician to give the worst possible advice in a matter which he does not understand, and to encourage a parent to accept bad advice when given by his trusted medical adviser.

The treatment of H is by supplementing the deficient refraction (*i.e.*, deficient relatively to the length of the axis of the eyeball) by means of neutralizing convex glasses, the effect of which is to advance the position of the principal focus of the eye to the actual position of the retina. The hypermetropic eye with its correcting glass forms a compound dioptric system, whose nodal point is farther from the retina than is the case when the same eye is focussed for distance by the exercise of its accommodation; the retinal image is, therefore, somewhat enlarged by the glass, and when the correcting glass is placed, as is usually the case in wearing spectacles, at or very near the anterior focus of the eye (about 15 mm. in front of the cornea) the size of the retinal image is found by calculation to be the same as in the emmetropic eye. With the exact correction of Ht the hypermetropic eye becomes, therefore, practically emmetropic, with normal region of accommodation; no part of the accommodation is expended in focussing parallel rays in distant vision, and A is rendered available in its entirety to meet the requirements of near vision. H *absoluta*, H *relativa*, and H *facultativa* being alike reduced to emmetropia, the conflict between accommodation and convergence ceases, and the patient is relieved of his asthenopia and of any pre-existing tendency to crossing of the eyes in the act of accommodation for distant or for near objects. The neutralizing convex glass required for the exact correction of Ht is that which, under complete relaxation of the accommodation, gives the maximum acuteness of vision at a distance.

The accurate correction of Ht is, therefore, the end to be kept constantly in mind in giving convex glasses to a hypermetrope; nevertheless, it is often better to reach this full correction by successive stages. Thus a young hypermetrope with large Hl may find it impossible to relax his accommodation fully on first using convex glasses, and may, therefore, reject neutralizing glasses as impairing distant vision and compelling him to read or work at an inconveniently or uncomfortably short distance. On the other hand, he will probably take very great satisfaction in somewhat weaker glasses which correct, or perhaps slightly overcorrect, his Hm. After wearing such partially correcting glasses for a few days or weeks a larger fraction of Ht will have been rendered manifest, and the glasses may then be changed for others of shorter focus, and these again for others, until the full correction of Ht is reached. Proceeding in this way, we may give the patient from the start all the help which he can receive from glasses, and at the same time spare him the inconvenience and possible disqualification for work attendant upon the production of complete artificial paralysis of the accommodation. If the previous condition of the patient has been that of H *absoluta*, the glasses first given will fully correct the manifest hypermetropia, and will enable him to see distinctly at a distance, and also to read unless he is also presbyopic; if of H *relativa*, they will relieve the accommodation both in distant vision and in reading, and will in a great measure do away with the necessity for excessive convergence in order to see distinctly; if of H *facultativa*, they will make it possible to use the eyes for finer work and for a longer time without fatigue. In proportion as Hl becomes merged in Hm, through the wearing of the weaker glasses, the change to stronger convex glasses renews the good effect of the former, until at length the full correction of Ht is accepted.

When, through uncorrected H *relativa*, accommodative insufficiency or periodic convergent squint has been developed, these symptomatic conditions usually disappear with the wearing of neutralizing glasses, and the eyes recover the power of working easily and harmoniously together in binocular vision. As the glasses afford needed aid to the accommodation, as well in distant as in near vision, they should, as a rule, be worn constantly; and to this end they should be mounted as spectacles rather than as a *pince nez*, and should be fitted with elastic bows curved behind the ears (see *Spectacles*).

If convergent strabismus has become already established, the effect of convex glasses is first of all to do away with the causes which incite to further development of the squint, and thus to arrest it in its actual stage. Secondly, they tend to diminish the existing grade of deviation, and in some cases, especially of recent squint, they may even suffice to bring back the optic axes almost immediately to their normal direction, and thus re-establish binocular vision. In other cases the full effect of the glasses requires a much longer time for its complete realization, which may be attained only after the lapse of many months or even of several years. Hence we should not hastily despair of finally curing even a pretty high grade of strabismus, when associated with a high grade of H, by glasses, even though the immediate effect be conspicuously inadequate; in such a case the use of strong convex glasses will sooner or later become imperative, on account of the visual disabilities incident to a high grade of H, and if worn only after a full correction of the squint by tenotomy, they may easily determine divergence of the previously crossing eye. In the presence of a high grade of H resort should ordinarily be had to surgical procedures only after the complete correction of Ht, and after the lapse of sufficient time to develop the full effect of the optical correction.

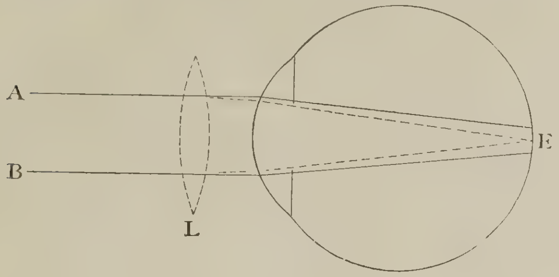

FIG. 2765.

The prompt correction of H by convex glasses is generally indicated on the first appearance of one or more of its characteristic symptoms (asthenopia, incipient strabismus convergens, or impaired distinctness of vision). They should, as a rule, be worn constantly during the waking hours, and it should be made clear to the patient, or in the case of a child to the parents, that they will probably be needed throughout life, in order to make it possible to use the two eyes easily and effectively in near work. Only in low grades of H, in which the rest afforded by weak convex glasses is not infrequently followed by a very marked amelioration of asthenopic symptoms, is it occasionally found practicable to lay them aside after this result has been attained (see also vol. i., pp. 583, 584, under *Asthenopia*).

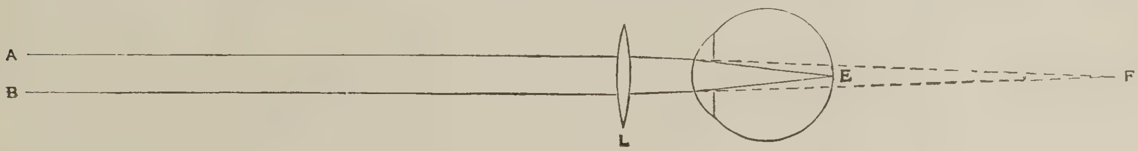

FIG. 2767.

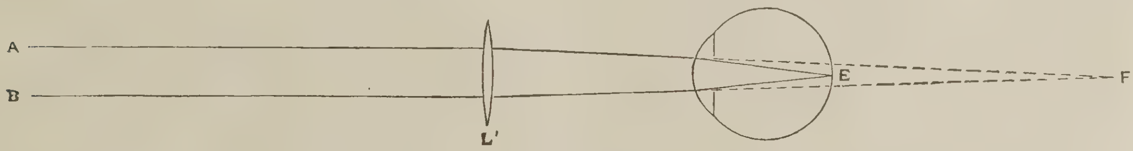

FIG. 2768.

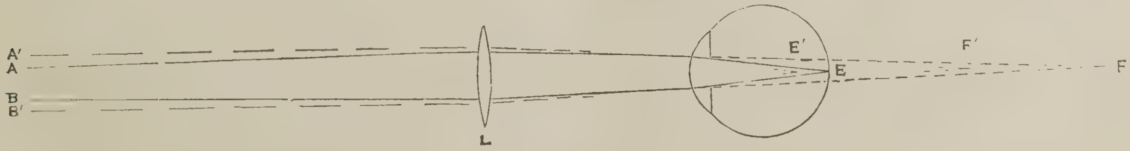

FIG. 2769.

APHAKIA.—Absence of the crystalline lens as a part of the dioptric system of the eye has been already noticed in this HANDBOOK (vol. i., p. 58). The deficiency in refractive power, as observed after the operation for cataract in an originally emmetropic eye, is so great as to necessitate the wearing of a convex glass of about 11 dioptries in order to raise vision to its maximum of acuteness at a distance, and a glass of 14 or 15 dioptries for reading. In the case of an eye previously myopic, a lens of less power than 11 dioptries suffices for distance, and for an eye previously hypermetropic a stronger lens is required. It follows that an eye with a pre-existing myopia of very high grade may, after the loss of its crystalline lens, be found to be nearly or quite emmetropic, and cases are occasionally observed in which, after an operation for cataract, no glass is required to bring out the maximum of visual acuteness for distance, and in which a convex glass of only 3 or 4 dioptries is required for reading. On the other hand, a glass of as high power as 20 dioptries may be needed for distance in a case in which there has been a pre-existing H of high grade, and a still stronger glass, of 23 or 24 dioptries, will then be required for reading.

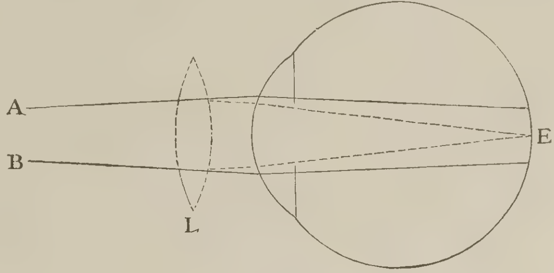

FIG. 2766.

As a consequence of the very great diminution in refractive power due to the loss of its crystalline lens, the unaided aphakial eye is unfitted for the performance of its proper function as a camera obscura. Fig. 2765 illustrates the insufficiency of the refraction at the cornea, in the absence of the crystalline lens, to focus the pencil of parallel rays, *A*, *E*, *B*, except as it is first converted into a convergent pencil by means of the convex lens *L*. Fig. 2766 similarly shows a divergent pencil, such as reaches the eye from a near object, rendered convergent by a stronger convex lens, to be focussed upon the retina at *E*.

Besides the diminished refractive power in the aphakial eye, there is also entire loss of accommodation. Hence the necessity for a stronger glass for near than for distant vision. The distance of the correcting-glass from the eye is, however, a matter of very considerable importance. Fig. 2767 represents an aphakial eye corrected, by the strong convex lens *L*, for focussing the pencil of parallel rays, *A*, *E*, *B*, upon the retina at *E*; the parallel pencil is converted by the lens *L* into a convergent pencil having its focus at a certain point, *F*, behind the retina, from which point the refractive power of the aqueous and vitreous humors, as determined by the convexity of the cornea, is just sufficient to advance the focus to *E*.

Fig. 2768 shows the same aphakial eye, with parallel rays focussed at *E* by the help of a weaker convex lens, L′, placed at a greater distance from the eye. In Fig. 2769 the lens *L*, which is of the same power as in Fig. 2767, is shown removed about an inch farther from the eye, and with its focus for parallel rays advanced, by the same distance, to *F′*, from which position the refractive power of the eye would advance it still farther to *E′*, which lies within the distance of the retina. A pencil, *A*, *E*, *B*, diverging from the conjugate focus of the lens *L* is, however, focussed by the lens at the distance of *F*, and, through the further refraction at the cornea, at *E*. By thus removing the correcting glass farther from the eye, we increase the refractive power of the combined dioptric system, made up of the lens *L* and the aphakial eye, and so may provide, in some sort, a substitute for the lost accommodation.

The position of the (single) nodal point of the aphakial eye (at the centre of curvature of the anterior surface of the cornea) coincides very nearly with that of the (second) nodal point in the perfect eye when in a state of complete accommodative relaxation. The effect of the convex glass worn in front of the aphakial eye (Figs. 2765, 2767, and 2768) is to form (with the eye) a compound dioptric system whose (second) nodal point falls farther forward (farther from the retina) than in the original (perfect) condition of the same eye. The retinal image formed by the help of the strong convex spectacle lens is, therefore, notably larger than the image of the same object in a normal eye of the same dimensions and corneal curvature. In the case of an aphakial eye wearing a convex lens of 13 dioptries 15 mm. in front of the vertex of the cornea, the ratio of the size of the retinal image to that of the image in the perfect eye is about 1.32 : 1. In the case of a convex lens of half the strength (6.5 dioptries), mounted 105 mm. in front of the cornea, the ratio is about 2.64 : 1, which is nearly equal to the magnifying power of an ordinary opera-glass.

Owing to the entire absence of accommodation in aphakia, Hl = 0, and Hm = Ht; hence all distinctions of Hm and Ht, and of H *facultativa*, H *relativa*, and H *absoluta* disappear, and the aphakial eye either sees distinctly, when it is perfectly corrected for the distance of the object, or indistinctly, when it is left uncorrected or is imperfectly corrected. The conflict between accommodation and convergence, which in H gives rise to asthenopia or to strabismus, has therefore no existence, and if either of these symptomatic conditions is developed in a case of uniocular aphakia, the causes must be sought elsewhere than in the aphakial eye.

Notwithstanding its great refractive deficiency, and the consequent imperfect definition of its retinal image, an aphakial eye, though uncorrected, may continue to take part with its fellow in binocular vision, and may thus render valuable service, not only by conserving the binocular field of vision in its normal extension, but also by aiding, to a useful extent, in the recognition of differences in distance (stereoscopic vision). Very often, however, binocular vision is not fully regained after the removal of an opaque lens, and the aphakial eye is then especially prone to acquire a false direction. In the presence of H in the fellow-eye, an aphakial or otherwise materially defective eye may become crossed; on the other hand, the co-ordination of function of the recti interni muscles of the two eyes with each other, and with the accommodation in the eye which still retains this faculty, may become impaired, and the aphakial eye may then gradually assume a divergent direction, notwithstanding the presence of such a grade of H in the fellow-eye as would ordinarily give rise to marked convergence. In acquired binocular aphakia, following a double operation for senile cataract, the convergence ordinarily remains fully under control, and, in the absence of pre-existing deviation of the axis of one of the eyes, binocular vision is generally retained.

In the otherwise perfect aphakial eye a properly selected convex glass restores nearly or quite normal acuteness of vision at the particular distance for which the correction is given, and, by reason of the considerable magnifying effect of the glass, vision may occasionally be raised even above the accepted normal standard of $\frac{5}{5}$. A moderate excess or deficiency of power in the correcting glass for distance is of no other importance than that vision is left somewhat deficient in acuteness, but reading glasses of excessive power may, in binocular aphakia, give rise to undue strain upon the recti interni muscles by bringing the reading distance too near to the eyes.

In uniocular aphakia, so long as the fellow-eye retains normal or nearly normal acuteness of vision and is without notable refractive defect, it is a frequent practice to leave the aphakial eye uncorrected. In cases in which the condition of the other eye is such as to call for the wearing of a correcting glass, it is generally practicable, and often desirable, to prescribe also the proper correction for distance for the aphakial eye. A tendency to divergence of an aphakial eye, in a young person, may often be arrested by wearing for a time a concave glass, of from 1 dioptrie to 3 dioptries, before the emmetropic fellow-eye, at the same time correcting the aphakial eye as accurately as possible for distance.

The first adequate description of H is by the English surgeon James Ware, in the Philosophical Transactions for 1813. Ware recognized the condition as "occurring in young persons"; as dependent on refractive insufficiency due to "a disproportionate convexity of the cornea or crystalline lens, or of both, to the distance of those parts from the retina"; as not involving "the power by which the eyes are adapted to see at distances variously remote" (*i.e.*, the accommodation); as "requiring a glass of considerable convexity to enable [the person] to see distinctly, not only near objects, but also those that are distant"; as of such a nature that "the same glass will enable many such persons to see both near and distant objects"; and as differing from the condition existing after the loss of the crystalline lens, the subjects of which "always require a glass, to enable them to discern distant objects, different from that which they use to see those that are near." In short, the description of the visual conditions in H *absoluta* and in most cases of H *relativa* is complete, and Ware is justly accredited by Donders with the discovery of H—a discovery which was, however, destined to remain almost fruitless for nearly half a century.

Ruete (1853) proposed the very appropriate name *Uebersichtigkeit* for this condition, but his description falls short of that of Ware in clearness and accuracy.

Stellwag (1855) described H correctly, as a condition in which the principal focal length of the eye is greater than the actual distance of the retina; but, in proposing for it the name *hyperpresbyopia*, he failed to emphasize its independence of accommodative insufficiency.

Donders (1859–60) first studied H exhaustively in its relation to different conditions of the accommodation, and gave to it its now universally accepted name. The present article is little more than a *résumé* of the principal facts established by that admirable physiologist, as embodied in his great work on the "Anomalies of Accommodation and Refraction of the Eye," New Sydenham Society, London, 1864.

John Green.

[For the convenience of the reader the following list of abbreviations used in this article is appended, following Donders, but with a few changes in form necessitated by the adoption of the modern metric notation.

H = Hypermetropia; Hm = H *manifesta*; Hl = H *latens*; Ht = H *totalis*; M = Myopia; A = Absolute range of accommodation; A_1 = Relative range of accommodation; A_2 = Binocular range of accommodation.]

HYPERNEPHROMA is a term suggested originally by Birch-Hirschfeld, and since adopted by other writers, to designate tumors that result from proliferation of adrenal tissue—it being immaterial whether the tumors arise in the adrenal itself or in regions where aberrant or misplaced (heterotopic) portions of adrenal tissue are known to occur. Though the terminology that suggests hypernephroma is not scientific, it finds justification in the peculiarities of structure of adrenal tumors and in the fact that the precise histogenetic position of the adrenal has not yet been determined. Lubarsch speaks of these tumors as hypernephroid tumors or tumors after the type of the adrenal with or without destructive characteristics.

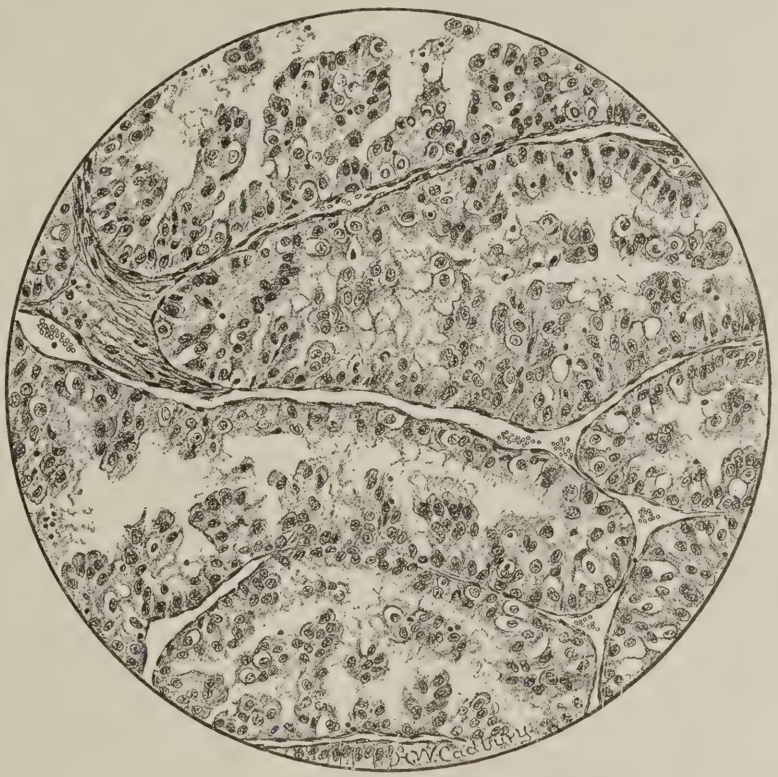

FIG. 2770.—Section of a Hypernephroma. Hæmatoxylin-eosin preparation. Zeiss apochrom, 8 mm., compens. oc. No. 4. For the most part the stroma consists of naked and intact capillaries that contain some blood corpuscles and that in some places are considerably dilated (more dilated than is usual). For the most part also the cells are attached directly to the endothelium of the capillaries, and they show marked fatty infiltration. In the section depicted the tumor presents large alveoli-like formations with central necrosis. In the upper right-hand region there are a number of high columnar cells.

During recent years considerable attention has been directed to the occurrence of *accessory adrenals* and to the great variety of displacements, in whole or in part, to which the adrenals are subject. Thus one or both adrenals may be absent; and the adrenal, if present, may be intimately adherent to the kidney and portions of its tissue may be displaced within the kidney. Accessory adrenals or portions of adrenal tissue have been found in the immediate vicinity of the normal situation of the adrenal, in the adjacent retroperitoneal connective tissue, in the kidney (usually directly beneath the capsule), about the renal blood-vessels, in the spermatic cord, between the testicle and the epididymis, in the inguinal canal, in the broad ligament (Marchand's adrenal), in the solar plexus, in the cœliac ganglion, in the liver, in the pancreas, etc. These accessory adrenals usually occur singly, though there may be more than one. They are yellowish in color, rather firm in consistence, and they vary in size. Usually they are about 2 to 3 mm. in diameter, but they may be so small as to be detected only by microscopical examination, and when the seat of hyperplasia or of tumor formation they may reach the size of a man's head. As a rule, they consist of one, two, or all three layers of the cortical substance; rarely medullary substance also is found. Schmorl states that they may be found in ninety-two per cent. of all bodies—a statement that has not found concurrence on the part of other observers. Presumably tumor formations may result from proliferation of any accessory adrenal; especial interest, however, attaches to the occurrence of adrenal tumors or hypernephromas in the kidney and in the broad ligament.

In the kidney adrenal rests are found usually at the upper pole of the organ, in the cortex, and directly beneath the capsule. Sometimes they are themselves entirely encapsulated, being separated from the subjacent kidney tissue by a band of well-developed fibrous connective tissue. In some cases through openings in this connective-tissue capsule portions of adrenal tissue invade the kidney, and in other cases no connective tissue whatever separates one tissue from the other. The kidney tissue adjacent to the misplaced adrenal tissue may present no deviations from the normal, but what is of especial interest and importance is that in some cases cysts, evidently dilated uriniferous tubules, are present at the junction of the two tissues, and that in other cases (as illustrated by one of my own cases) areas of kidney tissue are entirely or almost entirely included within these misplaced adrenal rests.

It is scarcely pertinent in this connection to discuss the different tumors of the adrenal that in a strict sense may be included within the scope of the designation hypernephroma. It will suffice to describe that class of tumors variously designated lipomas, adenomas, carcinomas, sarcomas, adenosarcomas, angiosarcomas, endotheliomas, and peritheliomas of the kidney—tumors the true nature of which was first recognized, in 1883, by Grawitz, who referred them to proliferation of aberrant adrenal rests. The opinions of Grawitz have been abundantly confirmed by Wiefel, Hollen, Ambrosius, Chiari, Strübing, Löwenhardt, Beneke, Horn, Marchand, Ulrich, Lubarsch, Askanazy, McWeeney, Manasse, Gatti, Ricker, Warthin, Pick, myself, and others.

Hypernephromas of the kidney (as well as hypernephromas of the broad ligament and of other structures) may be small and benign or large and malignant. The small tumors usually are situated in the cortex of the kidney; they are well circumscribed, generally encapsulated, nodular, yellowish or yellowish-white, and moderately firm. The larger tumors, which may attain a great size, replace more or less the kidney structure, though even in the largest tumors a narrow layer of compressed and distorted kidney tissue usually limits the tumor below. Usually, though not always, the tumor is separated from the remaining kidney structure by a more or less complete and intact connective-tissue capsule. In many cases, however, the capsule has become invaded and penetrated by the growth, and careful search is necessary to detect even remnants of it. It is nevertheless one of the characteristic features of hypernephromas. The tumor consists of spheroid or ovoid nodes that vary in size and are separated from one another by bands of connective tissue. Each node in turn is made up of smaller nodules into which as a rule but very little connective tissue penetrates. On section the growth is whitish (like brain medulla), or grayish-white or yellowish-white, sometimes reddish-white or brownish-white in color, opaque though sometimes glistening, and moderately firm in consistence in the well-preserved areas. The tumor exhibits a marked tendency to different retrograde changes, necroses, fatty metamorphoses, hemorrhage, etc., in consequence of which softening and pseudocystic formations may develop. True cystic formations are not uncommon, and in rare instances calcification may occur. The tumor may invade and finally penetrate the pelvis of the kidney. Invasion and penetration of the renal veins also is quite common, and in this way—that is, by way of the blood-vessels—if not exclusively, at least in the vast majority of cases, metastases may occur. These have been observed in almost all the tissues of the body.

On microscopic examination, the smaller hypernephromas reveal as a rule a well-formed connective-tissue capsule that recalls the capsule possessed by adrenal rests in the kidney; it may be complete, surrounding the tumor on all sides, or it may cover the tumor only on the surface. Even the larger and malignant hypernephromas sometimes are well encapsulated, and, even in those cases in which the capsule has become penetrated, remains of the capsule are often evident—a feature, as already pointed out, that constitutes one of the characteristics of this variety of tumor.

Histologically a hypernephroma is a tumor that consists of a stroma made up of a rather close network of capillaries, and of cells intimately associated with the capillaries and arranged in rows, columns, or masses within the meshes of the vascular network. The cells are epithelial in appearance and contain fat and usually glycogen. The tumor in cell-forms, cell-arrangement, and cell-contents reproduces or resembles the adrenal and certain tumors derived from the adrenal, and differs entirely in structural peculiarities from tumors derived from the uriniferous tubules.

The small and benign hypernephromas reproduce exceedingly well the structure of the adrenal and of certain tumors—so-called strumas or adenomas—that develop from the cortex of that organ. The larger and typical hypernephromas consist of nodules that vary somewhat in size and that are separated from one another by more or less delicate trabeculæ of connective tissue. As already pointed out, the stroma consists of a rather close network of capillaries. Frequently these are collapsed and scarcely apparent—whence in some cases on superficial examination, the tumor presents an appearance suggesting an adenoma for which it has frequently been mistaken. In many areas, however, the capillaries are quite apparent, and in certain areas sometimes they are much distended and more or less filled with blood. They may be demonstrated readily by injection procedures. The single layer of endothelium of which the capillaries consist is usually well preserved, though sometimes it may be the seat of some proliferation. In some cases the capillary stroma here and there is reinforced by a slight amount of connective tissue that proceeds as delicate trabeculæ from the connective tissue limiting the nodule. This is found especially in those tumors that present large alveolar-like formations and that are likely to be mistaken for carcinomas or alveolar sarcomas. In rare instances the connective tissue may exhibit some fatty infiltration.

The arrangement of the tumor cells within the capillary network recalls the zona fasciculata of the adrenal cortex, that is, the cells are arranged in rows or double rows, or in columns or cords. The tumor cells are attached directly to the walls of the capillaries—to the endothelium. This association of the capillaries with the tumor cells is one of the distinctive characteristics of hypernephromas and is absent only in those regions where a small amount of connective tissue reinforces the capillaries. The tumor cells vary somewhat in shape; for the most part they are polygonal, but they may be columnar, cubical, roundish, or irregular. The cell protoplasm is sometimes faintly granular, sometimes homogeneous, and exhibits usually rather large vacuoles—residua of extracted fat. The cells are epithelial in appearance and they contain one, sometimes two nuclei each, that are large, round, or ovoid; these stain well and reveal distinct nucleoli that are often metachromatic.

The arrangement of the cells into solid cords, though present in many tumors, is not so common as is their arrangement into rows and double rows with an intervening free space—an appearance extremely suggestive of adenoma formation (on superficial examination only, since the presence of the capillary network and the intimate association of the tumor cells with the capillaries immediately excludes all thought of adenoma formation). In these cases on cross section of the capillaries the cells appear attached to them as radii; on longitudinal section of the capillaries the cells appear arranged along the walls of the vessel in rows—palisades, as it were. On transverse section of the vessels that reveal the radial attachment of the cells, the attached ends of the cells frequently appear narrow and slender, their free ends swollen, rounded, and club-shaped. In these cells the nuclei are usually situated at the club-shaped extremity, though they may be situated at different heights, so that an appearance suggestive of a double layer of epithelium is produced. The free ends of a row of cells attached to one capillary in many areas are in contact with the free ends of a row of cells attached to an adjoining capillary. In many places between two adjoining rows of cells there is a space filled in part with cells similar in appearance to those attached to the capillary, and in part with cell detritus. These are especially common in those tumors that reveal rather large intercapillary spaces—tumors that morphologically resemble a carcinoma or an alveolar sarcoma. Into some of these spaces papillary excrescences appear to project a short distance.

The fat contents of the cells, though not uniform in all parts of the tumor, constitute a characteristic feature of hypernephromas. It is distinctly a fatty infiltration. In sections that have been prepared by the use of alcohol and ether the fatty infiltration is represented by vacuoles, that usually are large though they may be small. In some cases the fatty infiltration is so marked and the vacuoles are so large that only the nuclei and the outlines of the cells are to be detected.

Glycogen is a common constituent of these tumors. It is present in almost all cases, in all the tissues, and in different forms, generally as granules of varying size. In the differential diagnosis of kidney tumors, Lubarsch attaches considerable importance to the presence of glycogen, a substance that he believes is present in hypernephromas but not in true kidney tumors. This opinion is not shared by some other observers, and I have myself found glycogen in a primary cylindrical cell carcinoma of the kidney, as well as in tumors of other organs. Importance, however, it does possess.

Diagnostic importance attaches also to the presence in hypernephromas of intense black pigment granules, pigment granules similar to the pigment normally present in the adrenal cortex. In addition, considerable blood pigment, that gives the iron reaction, is usually found.

Lecithin, a substance to which Lubarsch, following Alexander, directed attention, and which Gatti found in a hypernephroma, may possess some diagnostic importance. This substance is found in the normal adrenal, in greater amount in the medulla than in the cortex. Gatti by chemical investigation found it in his tumor in amount approximating that of the normal adrenal cortex. As, however, we possess no microchemic reaction for its detection, it loses considerable of its otherwise possible differential diagnostic importance.

Variability in the histologic structure of hypernephromas has been repeatedly noted; they have been described as presenting an alveolar, a tubular, and a trabecular appearance. In some cases marked atypical proliferation may occur. Thus there may occur large alveolar-like formations in which only the cells directly in contact with the capillaries are well preserved, and these cells may be attached to the endothelium not regularly as palisades, but irregularly. The nuclei are frequently hyperchromatic and irregular; in some cases they exhibit karyokinetic figures. In some hypernephromas, generally large and malignant growths, giant cells, containing three, four, or more nuclei, may occur. Not infrequently the small veins are totally occluded by the tumor cells, and in this manner, that is, by way of the blood-vessels, metastasis occurs. The metastatic nodules reproduce the structure of the primary growth. As already pointed out, hypernephromas exhibit a marked tendency to the occurrence of hemorrhage and different retrograde metamorphoses. These are particularly manifest upon microscopic examination.

Especial interest attaches to the occurrence of cysts in hypernephromas. It suffices to mention that many so-called cysts may be merely dilated capillaries or lymph vessels. Other so-called cysts are doubtless but enlarged spaces between adjoining rows of cells of which mention has already been made—spaces more or less filled with degenerating cells and cell detritus. But other cystic spaces lined with well-formed cylindrical epithelium are evidently true cysts. Some time ago Ricker drew attention to the association of cyst formation and misplaced adrenal rests. He supposed that new growths of the adrenals may originate from misplaced kidney rests, and that certain tumors of more than ordinarily irregular formation—generally containing true cysts and therefore atypical hypernephromas—may develop from adrenal tissue that has either enclosed or is otherwise intimately associated with renal rests, commonly in the form of small cysts. My own investigations bear out the probable correctness of this opinion. I have already referred to the occurrence of cysts, evidently dilated uriniferous tubules, at the junction of adrenal and kidney tissue in some cases of misplaced adrenal rests, and to the partial or complete enclosure of kidney tissue within misplaced adrenal rests. It is warrantable to assume that, in the event of proliferation of the adrenal rests, the enclosed kidney tissue proliferates also, and gives rise to certain well-formed cysts with cylindrical epithelium.

As an additional proof of the adrenal origin of these tumors of the kidney, it is of interest to mention the similarity that they bear to tumors that develop in the adrenal itself and do not implicate the kidney.

The small and benign hypernephromas rarely give rise to clinical manifestations; commonly they are accidental findings at the necropsy. The larger and malignant hypernephromas give rise to symptoms that scarcely permit of their clinical differentiation from other tumors of the kidney. Hypernephromas occur at any age, even in new-born infants, though they are more common in adult life; they appear to occur more frequently in women than in men; they involve either kidney indiscriminately; they vary in duration from several months (apparently) to a number of years; and they vary in size from that of the smallest adrenal rest to that of a man's head. It has been pointed out by a number of observers that hypernephromas are characterized clinically by the fact that they pursue a long benign course entirely devoid of symptoms (though it is difficult to conceive how this can be recognized clinically), and that then suddenly they take on malignant characteristics, proliferate rapidly, give rise to metastases, cachexia, and the death of the patient, unless they be removed by surgical procedures. It has been said also that a hypernephroma may be inferred from the detecting of a murmur upon auscultating a tumor of the kidney. Perhaps hypernephromas may be diagnosed clinically when it becomes more generally recognized that primary carcinoma of the kidney (developing from true kidney structures) is uncommon, and that most of the so-called primary carcinomas and alveolar sarcomas of the kidney are in reality hypernephromas.*

Aloysius O. J. Kelly.

HYPERTRICHOSIS.—(Synonyms: Hirsuties, Polytrichia, and Superfluous Hair.) By hypertrichosis is meant either an abnormal amount of hair growing in a location where hair normally is found; or the appearance of sexual hair at an unusual age upon a part which later normally is covered with hair; or the growth of coarse hair on a part usually covered only with lanugo hair.

Instances of the first variety are occasionally seen. Thus Leonard reports the case of a man whose beard measured six feet six and a half inches in length. There is said to have been a man in Eidam, Holland, whose beard was nine feet long; and the Burgermeister of Braunau rejoiced in a beard that reached to the ground. Women have been known to have hair that trailed behind them on the ground.

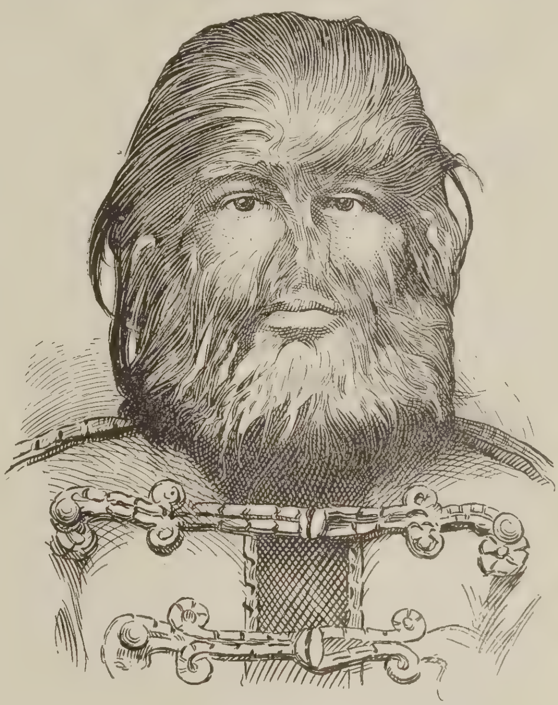

FIG. 2771.—The Russian Dog-face Boy.

Precocious development of hair is technically called *heterochronie.* This variety includes cases of a beard growing on the face of a young boy; and of well-developed pubic hair in children of tender years. Such cases are rare.

Most cases of hypertrichosis belong to the third variety, that is, the growth of coarse hair in places usually supplied only with lanugo hair. Of such are the growth of coarse hair in the nostril and ears in people past middle life; of hair on the back of the nose, and about the nipples and on the chest of women. The two chief forms of this variety of hypertrichosis are the universal form and the growth of the hair on the face of a woman.

The subjects of *universal hypertrichosis* are technically called Homines pilosi. This is a very rare form, and is both congenital and hereditary. The whole body is covered with long hair except in those locations upon which hair never grows, namely: the palms of the hands, the soles of the feet, the backs of the last phalanges of the fingers and toes, the inside of the labia majora, the prepuce and glans penis. The hair of the trunk is somewhat softer than that of the pubic region and scalp. Both sexes are affected in much the same way. The hair grows away from certain well-defined centres. On the forehead it grows to the right and left from a line down the middle of the forehead; on the back downward and outward from the spinal column; and the common centres of distribution are preserved upon the limbs and scalp. With the excessive growth of hair there is a deficiency in the development of the teeth, and the subjects of this deformity are usually of small size.

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* For references consult Kelly, A. O. J.: "Ueber Hypernephrome der Niere." Ziegler's Beiträge zur pathologischen Anatomie und zur allgemeinen Pathologie, xxviii., 280, 1898; and "On Hypernephromas of the Kidney." Philadelphia Medical Journal, ii., 223, 283, 1898.

Reports have been published of several families of hairy people. Perhaps the best known is the Kostroma father and son, both of whom have been exhibited before the public. The son was for some years in a circus combination in this country under the name of "The Russian Dog-faced Boy." The writer saw him in 1886 when he was sixteen years old. He seemed to be a well-developed boy, though short in stature, muscular, active, energetic, and intelligent. He was said to be in good health and good-tempered. The accompanying picture shows the growth of the hair on his face. The hair was fine, glossy, blond, and about four inches long. The trunk was covered with hair that was specially well-marked down the spinal column, where it stood out like the mane of a horse. The body hair was very fine and more fluffy than that on the face. He had a cast in one eye and was near-sighted. He had only five teeth, two upper canine, and two lateral and one middle incisor, and these were misshapen and discolored.

Partial Congenital Hypertrichosis is of more frequent occurrence than is the universal form.

Many of the so-called cases are instances of nævus. True cases are most often associated with spina bifida, a growth of long hair being found on the lumbar region. Ornstein (*Berlin. Gesellschaft f. Anthropol.*, 1876, 1877, and 1885) says that sacral hypertrichosis is very common among the Greeks, and reports two cases of tails in Greek soldiers. One was one quarter of an inch long and cone-shaped; the other was not so long and was stumpy.

Bearded Women.—This is the form of hypertrichosis that is of most interest. Hair appears on the face of a woman at two distinct periods of life, namely, at puberty, and at middle life in connection with the menopause. The most difficult cases to manage, because the amount of the hair is the greatest, is the form that begins in early life. As in a man the hair continues thickening in amount until twenty-five or thirty years of age. At first the growth is fluffy, fine, lanugo-like. If left alone it may remain so for many years. If attempts are made to destroy it by pulling, shaving, or using depilating powders, it grows more rapidly coarse. Even if left to itself it will grow coarser in time. While all the regions spoken of as the bearded portions of the face are affected in pronounced cases in women, the growth is usually most marked on the upper lip and chin. In a few cases the beard is as coarse and full as that of the average man, though commonly there is but little hair on the lower lip. Such a growth on the face of a young woman may have a bad effect on her mind. She is apt to become abnormally sensitive about even a very moderate growth, attempts in many ways to destroy it, and only makes matters worse; in some instances she may become insane.

When the hair does not begin to grow coarse until the menopause it rarely grows to any great extent. Commonly there are only a few stiff hairs scattered about the chin and on the upper lip.

Transitory Hypertrichosis is met with. Such are growths of hair on a limb which has been for some time confined in a fracture box; that which comes after injury to certain nerves; that which follows prolonged irritation of a part by blisters. In such cases the exciting cause being removed the hair falls from the part. In some women the hair will grow on the face during pregnancy or amenorrhœa, the hair disappearing after delivery or the relief of the amenorrhœa.

Etiology.—Many theories have been formed to account for general hypertrichosis. Unna's theory is probably correct, which is that it is due to the persistence of the fœtal or primitive hair, the change in type from the fœtal to the permanent hair for some reason not taking place. It is known that at a certain time in its intra-uterine life the fœtus is covered with fine hair. Before birth this hair is all shed. Some children do not complete the change in type until a short time after birth. In the general hypertrichosis cases no change in type occurs. The occurrence of subsequent cases in the same family is doubtless due to heredity.

The cause of hirsuties on women's faces is heredity in the great majority of cases. Reversion to the male type, the woman bearing a markedly strong resemblance to her father, may account for some cases, and perhaps for the first case in a family that afterward shows this trait in many of its women. That there is some relation between proper functioning of the organs of reproduction and the hair on the face, as shown by absence of the one and the presence of the other, is evident; still in the great majority of patients no such relationship can be traced. Such influence is most constant and most pronounced at the time of the menopause. Few of my patients have shown masculine traits, and many of them have been mothers of several children.

Local partial acquired hypertrichosis is due to an increased blood supply to the part from the application of blisters and the like. Certain forms of insanity are attended with hypertrichosis.

Treatment.—For universal hypertrichosis there is practically nothing to be done, not because the hair could not be destroyed, as in the partial cases, but because the work would be endless.

For partial cases due to local causes nothing need be done, because the hair falls of itself when the local stimulant ceases to act. It is in hirsuties in women that our aid is chiefly called for, and the treatment effective in that form is equally effective in all forms of partial acquired or congenital hypertrichosis. The only means at our command that is at all reliable is electrolysis, and that is absolutely effective. We owe this operation primarily to Dr. Michel, of St. Louis, who invented it for the destruction of ingrowing eyelashes, he being an ophthalmic surgeon. Dr. W. A. Hardaway, of the same city, first used it for the cure of hirsuties and introduced it to the notice of the medical profession.

The requisites for the operation are a constant-current galvanic battery, a sponge electrode, a needle-holder electrode, needles, a pair of epilating forceps with easy spring, good eyes, and a steady hand. A reclining chair that can be raised or lowered is a convenience. I always use a dentist's chair. If the operator's eyes are not good it will be necessary for him to wear glasses. A needle-holder electrode with a lens attached is on the market.

The patient must be placed in front of a window, preferably one with northerly exposure so as to avoid the glare of the sun. She is given the sponge electrode, moistened with a solution of baking soda, and attached to the positive pole of the battery. Some prefer that the positive pole should be immersed in a bowl of water, and that the patient place her fingers in this. The needle, which is either a steel jeweller's broach, No. 5, 7, or 8, or one of platinum, is placed in the needle electrode attached to the negative pole of the battery. The operator takes hold of the hair with the forceps, puts it slightly on the stretch, and passes the needle into the hair follicle alongside of the hair, and to a depth of about an eighth of an inch. If the needle is properly passed no resistance will be felt. If not, one feels the tissues give way under the pressure of the needle. The needle being in place, the patient is told to place her hand on the sponge or into the water, as the case may be, and thus the current is caused to run. The patient experiences a burning sensation somewhat like the sting of a bee, a little frothing takes place about the needle, and in a few seconds the hair will leave the follicle on slight traction. The hair is always to be removed by the operator. As soon as the hair is out the patient removes her hand from the sponge and the operator then withdraws the needle. It is important always to follow this exact order of inserting the needle before having the hand placed on the sponge, and removing it after the hand is taken off from the sponge so as to avoid the slight shock that otherwise would be felt.

The amount of current to be used varies with the patient's ability to endure pain, and with the place upon which it is necessary to work. A milliampèremeter is a comfort in working, and a current strength of 1 to 2 milliampères is adequate for the work. If one has not the metre the current strength may be roughly said to be that from six to eight freshly charged cells. Most pain is felt on the upper lip and the nearer to the nose we go the greater is the pain. From forty-five to seventy hairs can be removed in an hour. The coarser the hair the fewer can be removed in the time. There is no scarring in the majority of cases, excepting on the upper lip, where it is difficult to avoid slight pitting of the skin. Some skins will show the marks of the work in the form of pitting, just as some skins will develop keloidal scars after slight wounds. A certain number of hairs will come back, because it is not possible for any one exactly to hit the hair papilla every time. The returns will vary from fifteen to twenty-five per cent., and more if the operator is not skilled. This necessitates going over the face a second or third time. Care must be had not to take the hairs out in too close proximity, at least one hair being left between every two extracted. If this precaution is had the danger of scarring will be greatly reduced.

Attempts at destroying hair by other means have been made. Next to electrolysis the best method is probably by the use of what is called the *Microbrenner*, a fine needle heated to a white heat by an apparatus like the Paquelin cautery. I have had no experience with it, but some of our German confrères speak enthusiastically of it, saying that more hairs can be permanently destroyed by it in a given time than by electrolysis. Treatment by the x-ray is the most recent method. Permanent results have been reported. I should be afraid, however, to use this method on account of the danger of burning.

Depilating powders are worse than useless. They simply burn off the tops of the hair and have no effect on the roots. The consequence is that the hairs become rapidly coarser as in shaving. Those that are most used are one composed of sulphuret of barium, ʒ iss.; oxide of zinc, ʒ vi., and carmine, gr. i.; and one of sulphide of soda, ʒ ij., and prepared chalk ʒ vi. These powders are mixed with water at the time of using and thus made into pastes that are spread on the skin. The first is to be washed off in three minutes and the last in ten or fifteen minutes.

George T. Jackson.

HYPERTROPHY.—In its broadest sense hypertrophy is an increase in substance of an organ or tissue, due either to an increase in the number or size of its individual elements, or to a combination of both these changes, without other alterations of structure. An increase in size alone of the individual cells is known as *quantitative* or *true hypertrophy;* increase in the number of cells alone as *numerical hypertrophy* or *hyperplasia.* The gross changes in hypertrophy are: increase of size and weight, in the case of hollow organs a thickening of the walls; increase in consistence; and in the case of muscle a darker color due to an increased formation of muscle pigment. Hollow organs when viewed externally may not give evidences of hypertrophy, since the increase of size may take place at the expense of the cavity, as in the case of concentric hypertrophy of the heart. The weight of an organ is the most reliable standard for the judgment of hypertrophy, but it must be borne in mind that both increase in size and weight of tissues may be due to other pathological conditions than true hypertrophy or hyperplasia. It therefore becomes necessary to make sure that an apparently hypertrophic organ is of normal structure, and this is possible only on microscopical examination.

Microscopically, true hypertrophy is shown by increase in size of the individual cells with increase in size and staining power of their nuclei. Since there are individual differences in the size of cells a standard of comparison can be obtained only by the most exact measurement of the cells of the tissue in question. Hypertrophy of the nucleus may exist without enlargement of the cell body. The practical distinction between true hypertrophy and hyperplasia is often difficult; they usually exist together. Numerical atrophy may be combined with true hypertrophy, the cells may be increased in size, while diminished in number; on the other hand hyperplasia is often accompanied by a loss of bulk on the part of the individual elements. Only very rarely do all the cells of a tissue or organ show a uniform hypertrophy, atrophic cells usually exist side by side with those of increased size.

The causes leading to hypertrophy may be either intrinsic or extrinsic. In the former case morbid impulses to growth or multiplication either exist in the germinal cells or arise through germ variation. Such impulses may develop during either intra- or extra-uterine life. They may be ascribed to an increased tendency to growth and cell multiplication or to an absence of the normal inhibitory influences, but beyond such theoretical explanation we cannot as yet venture. Intrinsic hypertrophy is usually spoken of as congenital or inherited hypertrophy. The hypertrophies not dependent upon congenital tendencies are usually the result of an increased functional demand, increased nutritional activity, or of a disturbance of the normal equilibrium between growth and decay. Underlying hyperplasiæ are the factors leading to cell division.

Intrinsic Hypertrophy.—The more common forms of overgrowth due to congenital tendencies are: general and partial giantism, ichthyosis, elephantiasis, lipomatosis, hypertrichosis, hyperonychia, onychogryphosis, leontiasis, exostoses, etc. Hypertrophy due to congenital excessive impulses of growth rarely affects the internal organs; but certain hypertrophies of brain, thymus, lymph glands, spleen, etc., are at present explained as being of congenital origin. It is impossible to say to what extent the various forms of hypertrophy mentioned above as being of congenital origin are in reality the result of intrinsic forces, since similar proliferations, ichthyosis, elephantiasis, etc., may be caused by external influences. However, in those cases in which the hypertrophic growth is of hereditary nature and appears early without adequate extrinsic cause, the grounds for considering the existence of a congenital predisposition are very good. Even in those cases in which the overgrowth was excited by external injurious influences the existence of a congenital predisposition is not precluded, since we know by experience that such causes give rise to pathological changes of this nature only when there is a special predisposition inherent in the tissues.

Acquired Hypertrophy.—The most common varieties of hypertrophy due to extrinsic influences without the coöperation of congenital predispositions are: hypertrophy due to increased functional activity, hypertrophy caused by lessened wear, hypertrophy resulting from failure of involution, hypertrophy caused by removal of pressure, and finally hypertrophy caused by chronic irritation, either chemical, mechanical, or infectious.

Hypertrophy from overwork occurs most frequently in muscles and glands, rarely in other tissues. The physical and chemical changes in the muscle cell or gland cell resulting from increased function in some way stimulates cell growth. The degree of the hypertrophy depends upon the age of the individual and the general state of the nutrition. Increased work on the part of the heart due to valvular, arterial, pulmonary, or renal conditions causes a more or less marked hypertrophy of that part of the heart upon which the greater share of the work falls. Such hypertrophy being in compensation for the disturbances of circulation produced by the primary pathological condition is known as *compensatory hypertrophy.* Either side of the heart alone may be affected or the entire organ may become enlarged. Further, hypertrophy of individual muscle bands or layers may occur according to the functional demands of the case. Compensation is more nearly complete in the case of young and well-nourished individuals. Increase in bulk of the voluntary muscles follows increased muscular exercise. The fibres increase both in length and in thickness, and there is most probably an increase also in the number of the fibres. Hypertrophy of individual muscle groups occurs in certain trades or occupations (laborer's hypertrophy). Hypertrophy of the involuntary muscle occurs physiologically in the pregnant uterus, the muscle cells attaining a size of seven to twenty times the normal length and five times the normal breadth. In the case of uterine tumors and hæmatometra hypertrophy of the uterine wall may also occur but to a less degree. Hypertrophy of the muscular coat of blood-vessels occurs in conditions of increased blood pressure, particularly in the case of the dilatation of vessels in the establishment of a collateral circulation. In the case of enlarged prostate, urethral stricture, calculi, etc., the bladder walls may become greatly thickened; a similar hypertrophy of the muscularis of stomach and intestines may occur above a stricture.

Of the glandular organs the kidneys and liver are most capable of undergoing hypertrophy. In increased functional activity of the kidney, as in the case of diabetes and excessive drinkers, both kidneys may become enlarged. Compensatory hypertrophy of one organ may take place after the destruction or removal of the other, so that the remaining kidney may in size and weight equal or exceed that of two normal kidneys. The younger the individual, the more complete the compensation. On microscopical examination the enlargement is found to be due chiefly to a hypertrophy of existing structures, but in young individuals a hyperplasia of tubules and glomeruli also occurs.

Hypertrophy of the liver as a whole is extremely rare.

Destruction of a portion of the liver substance is followed by a hypertrophy of the remaining normal liver tissue. The lobules become larger and also increase in number. In animal experiments it has been shown that complete restoration of as much as half of the organ is possible. In simple or inflammatory atrophies of the liver hypertrophy of single cells is very common.

Destruction of one adrenal may be followed by compensatory hypertrophy of the other. In the case of the salivary glands, mammæ, ovaries, and testicles, compensatory hypertrophy does not take place at all or only to a slight degree, except during the developmental period. Hypertrophy of the mamma has been found in connection with galactorrhœa, and in one-sided lactation after loss of one breast.

Removal or destruction of a portion of the thyroid is rarely followed by hypertrophy of the remaining thyroid tissue, but the hypophysis suffers an enlargement which must be regarded as compensatory in nature. The writer has seen in a case of acromegaly an enormous hypertrophy of the parathyroids which might possibly be explained as being of the nature of a compensation for the hypophysis.

Agenesia or aplasia of one lung may be compensated by hypertrophy of the normal organ, and a similar compensation may occur in early life in conditions leading to disuse of one lung. In later years, however, the loss of one lung is followed only by an emphysematous distention of the other, which usually leads to atrophy of the alveolar walls and not to hypertrophy. Emphysematous distention of the air spaces with hyperplastic thickening of their walls has been observed in the lungs of athletes, singers, and players of wind instruments.

Compensatory hyperplasia of the different blood-forming organs, spleen, lymph glands, and bone marrow in conditions affecting one or the other is not uncommon. In various forms of anæmia, leukæmia, etc., where the function of either the spleen or bone marrow is inadequate, the hæmolymph glands become enlarged and suffer structural changes by which they come to resemble either splenic tissue or lymphoid marrow.

Compensatory hyperplasia of the fibula has been observed in cases in which through disease the tibia had been rendered useless in the support of the body.

Hypertrophy from lessened wear occurs particularly in the case of the nails and teeth. If the wear of the nails be prevented, or if they are left uncut, they may become very much enlarged. Teeth growing irregularly, so that the cutting or grinding surfaces are not brought into apposition develop into the so-called tusks. In animals the claws and beaks of birds, and the teeth of rodents may through disuse form extensive overgrowths.

Removal of pressure as in the case of atrophy of the brain may lead to a thickening of the inner table of the skull. Similarly in other regions of the body removal of the normal pressure is often followed by hyperplasia of the adipose tissue.

Failure of the normal involution of the uterus after pregnancy gives rise to an abnormally large uterus during the non-pregnant state. The thymus gland instead of disappearing at the usual period may persist or even show enlargement.

As the result of slight prolonged or frequently repeated mechanical irritation local hyperplasias of tissue may arise (local ichthyosis, callus, corns, etc.); hyperplastic overgrowths are also caused by chemical action (hypertrophy of bone caused by phosphorus and arsenic); and finally infective inflammations frequently give rise to overgrowths or new formations of tissue (condyloma, tuberculous and syphilitic processes, actinomycosis, etc.). Chronic inflammations of the skin are often characterized by hyperplasia of fibrous connective tissue resembling elephantiasis; in syphilis extensive overgrowths of bone not infrequently occur. In inflammatory affections of the lung and pleura, as well as in congenital heart lesions, enlargement of the terminal phalanges and articular ends of the long bones may occur (ostéoarthropathie hypertrophiante). The so-called clubbed or drum-stick fingers acquire an important diagnostic significance in these conditions. Hyperplasia of the spleen and of the lymphadenoid tissue throughout the body is of not infrequent occurrence. The nature of such overgrowth is as yet obscure, but it is most likely of infectious or toxic origin. In a number of cases the hyperplasia of the lymph glands has been shown to be an atypical tuberculous process.

The extensive hypertrophy of the bones and internal organs observed in the condition known as acromegaly forms one of the most interesting varieties of the acquired hypertrophies. The nature of this disease is as yet unknown; in the majority of the cases an adenomatous hyperplasia of the hypophysis has been present and this has been regarded as the cause of the disease. Other writers have explained it as due to a congenital predisposition, to disturbances of the pineal body, sexual organs, thymus, or thyroid, or to abnormal nervous influences.

General Considerations.—Both true hypertrophy and hyperplasia are to be regarded as being of unstable nature, inasmuch as they depend upon the duration of the cause and the increased supply of nutrition. Increase of size demands also increase of space, and in the case of some of the organs and tissues a space limit may be ultimately reached. Hypertrophic tissue requires hypertrophic vessels to furnish the increased amount of blood needed. Changes in the vessels or in the circulation by which the supply of nutrition is diminished lead quickly to atrophy and fatty degeneration of hypertrophic tissue. Similarly diminished functional activity, particularly in the case of the heart and voluntary muscles, is followed by rapid fatty degeneration of the muscle fibres. Further, the inherent vitality of cells, particularly their histogenetic vitality, is limited; tissues which have used up their reserve in compensating for some deficiency are the sooner exhausted. A heart in a state of compensatory hypertrophy may not be able to meet ordinary emergencies which under normal conditions have no effect upon the non-hypertrophied heart; that is, a heart though hypertrophic may be insufficient. Sooner or later, therefore, a failure of compensation must occur, such failure depending upon many factors: inherent cell vitality, conditions of nutrition and removal of waste products, functional activity, etc. In general it may be said that, while fully developed heart and voluntary muscles are desirable, compensatory enlargement due to excessive exercise, increased nervous stimuli, etc., as in the case of the "athletic heart," "smoker's heart," etc., must be regarded as distinctly pathological, inasmuch as such hypertrophy is at the expense of the heart's reserve power.

Aldred Scott Warthin.

HYPNOL.—This is the product of the combination of antipyrin and chloral in definite proportions. It was introduced by Bardet in 1890, who gives its preparation as follows: Mix a solution of 47 gm. of chloral hydrate in 50 c.c. of distilled water, with a solution of 53 gm. of antipyrin in 50 c.c. of distilled water, and after an hour remove the oily fluid from the aqueous layer. At the end of twenty-four hours this solidifies into a mass of rhombic prisms. The salt is colorless and soluble in five parts of water. It is said to have the combined effect of its constituent drugs and has been recommended as an hypnotic in sleeplessness, especially when accompanied by pain. The dose is from ten to fifteen or twenty grains. It has a less disagreeable taste, and is less disturbing to the stomach than either chloral or antipyrin and forms an excellent means of administering these two drugs, which are incompatible in all other proportions.

Beaumont Small.

HYPNONE.—Acetophenone, $C_6H_5CO.CH_3$. This chemical compound has long been known to chemists and classed as a ketone. It bears somewhat the same relation to chloral that ether does to alcohol. It is a colorless liquid at 70° F., very volatile, and possesses a sharp caustic taste and a penetrating odor, resembling bitter almonds. At 57.2° F. it solidifies. It is soluble in alcohol, ether, and fixed oils, but is not soluble in water or in glycerin.

Acetophenone was introduced as an hypnotic, in 1885, by Dujardin-Beaumetz and Bardet under the name of hypnone. It was thought to be of particular value in the insomnia of insanity, alcoholism, and nervous disorders. It, however, has fallen into disuse on account of the uncertainty of its action. The dose was given as from three to ten minims, but much larger quantities have been given without producing any effect. As much as twenty minims have been given hypodermically in cases of insanity. No bad effects have been recorded from its use. Experiments upon lower animals show that its prolonged use lessens the hæmoglobin of the blood and produces emaciation. Death is caused by respiratory failure, following muscular paralysis and coma.

Beaumont Small.

HYPNOSIS.—Hypnosis is a subjective, induced condition of the mind in which the normal influence of the judgment and volition are more or less restricted, while the susceptibility to suggestion is enormously increased. To the ordinary observer it seems to be a trance-like sleep, in which the mind of the subject becomes subordinate to that of the operator.

Hypnotism is that branch of mental science which deals with the phenomena of hypnosis and the methods for its induction.

Suggestion is any method of evoking in the mind of the subject an idea or association of ideas for the control of his mental activities. It becomes *hypnotic suggestion* when the subject operated upon is in a state of hypnosis. Suggestion is called *post-hypnotic* when the idea imparted during hypnosis is to be executed at a more or less remote period subsequent to awakening from the hypnotic state. It is the post-hypnotic suggestion primarily that is of therapeutic value in hypnotism.

Rapport is the relation that exists between the subject and the operator by whom the hypnotic phenomena are called forth.

To review the history of hypnotism would be beyond the scope of this brief article, but it is important to consider its salient points. Much of the mysticism and occult science of the middle ages, indeed of antiquity itself, can be explained through its employment.

Attention was first drawn to it in a definite way by Mesmer, a Viennese doctor, in the latter part of the eighteenth century. He maintained the existence of a force, which he called "animal magnetism" by means of which persons could influence one another, and it is this "animal influence" which constitutes the essential nature of mesmerism.

Much interest was manifested both by laymen and by physicians in Mesmer's claims, but in the early part of the nineteenth century Abbé Faria showed that the phenomena were wholly subjective and not at all dependent upon any unknown force.

In 1841 Braid, a physician in Manchester, England, gave the whole subject a new impetus by his more scientific experiments. His method of inducing hypnosis was by the process of fixation of attention, which resulted in a sleep-like condition, to which he gave the name "hypnotism." Under the influence of his teaching much progress was made in the elucidation of the subject, and it gained a more stable position in the domain of science.

Later, Lièbeault, of Nancy, after a thorough examination of the phenomena of hypnotism and animal magnetism, reached the conclusion that they were wholly dependent upon the influence of suggestion. Professor Bernheim, a pupil of Lièbeault, further developed this view, regarding hypnotic phenomena as physiological rather than pathological and wholly due to suggestions made by the operator.

In 1878 Charcot, the eminent French neurologist, began his studies in hypnosis as manifested in the large group of hystero-epileptics at the Salpêtrière Hospital. His observations, however, were confined to that class of subjects, and resulted in the doctrine that it was a "morbid neurosis dependent almost always on soil predisposed by hysteria." Suggestion he regarded as a "symptom of hypnosis, not its cause." (Art. "Hypnotism," Charcot, in Tuke's "Dict. Psychological Medicine," 1892, vol. i., p. 606.) Since that time the study has been taken up by psychologists as well as by physicians, the trend of opinion being rather in the direction of the Nancy school, which regards hypnosis as physiological rather than pathological. Suggestion is employed as the most important means for evoking it.

The nature of hypnosis, however, is far from being well established; neither Mesmer's assumption of a mysterious "animal force," nor Braid's doctrine of "fixed attention," nor the theory of "suggestion" of the Nancy school, nor yet Charcot's association of it with hysteria, is sufficient to explain its manifestations. The hypothesis of the dissociation of consciousness is a better attempt to furnish an explanation of its varied phenomena (see article *Consciousness, Disorders of*).

According to many psychologists much of the activity of the human mind takes place below the plane of consciousness, the so-called subconscious or subliminal mentality. In this domain lie many of the unconscious phenomena of feeling on the one hand, and of impulse on the other (see article on *Automatic Actions*). It is in the emergence of this subconscious mental field which is peculiarly susceptible to suggestion, simple or hypnotic, that Frederick Myers would explain hypnosis.

As it were, for the time being the subconscious mentality dominates the conscious mind and controls the intelligence, quite the reverse of the normal order. In this respect hypnosis is related to hysteria, the dream states of sleep, hallucinations of the insane, etc., but it is not necessarily a morbid phenomenon, nor dependent upon a morbid condition of the mind.

Suggestion serves then to call forth the phenomena. It is rather the signal for their manifestation than either the cause (Nancy school) or the symptom (Charcot).

The methods employed for the induction of hypnosis depend necessarily upon the views of the operator:

1. *Magnetic Method.*—Those who believe in animal magnetism assume that a special magnetic influence emanates from the operator upon the subject. Therefore standing in front, the hypnotist gazes fixedly upon the eyes of the subject and makes long sweeping passes from the head downward, believing that in some way the peculiar fluid streams from his fingers and thus best influences his subject.

2. *Fixed Attention.*—Braid's method consists in fixing the eyes upon a bright object placed a little above the eyes in the median line; the intent being to produce visual fatigue quickly through the undue strain of convergent strabismus.

In a successful experiment after a time the subject becomes relaxed, his eyelids tremulously close, and he appears to be in a semi-somnolent condition. This is the usual method of procedure, but is somewhat open to objection. The unusual nervous tension required at times has resulted in an acute hysterical attack.

3. *Method of Salpêtrière School.*—Charcot in his experiments upon hysterics established three more or less distinct states of hypnosis:

(1) The cataleptic state, produced—

(*a*) Primarily by the influence of a sudden intense noise, by a bright light flashed before the eye, or further by fixation, more or less prolonged, of the eyes upon any object;

(*b*) Secondarily, to the lethargic state when the eyes hitherto closed are suddenly opened to a bright light by raising the eyelids.

(2) Lethargic state, produced—

(*a*) Primarily by the influence of fixation of the eyes upon an object placed at a certain distance away;

(*b*) Secondarily to the cataleptic state, by simple closure of the eyelids.

(3) State of induced somnambulism, produced—

(*a*) Primarily in some subjects by fixation of attention, or

(*b*) Secondarily, easily with subjects already in a lethargic or cataleptic state, by making simple pressure or light friction upon the vertex.

In these various states of hypnosis certain characteristic phenomena are present. In the *cataleptic* condition the subject is immobile, he appears to be fascinated. The eyes are open, staring, and soon become suffused with tears. There is no winking of the eyelids. Very frequently there is anæsthesia of the conjunctiva and even of the cornea. The limbs and all parts of the body preserve their position for a long time, even attitudes very difficult to maintain which may have been given them—a "wax-like flexibility" very characteristic. The tendon reflexes are abolished and neuromuscular hyperexcitability is absent. While analgesia is complete, certain senses, muscular, visual, and auditory, preserve their activity. This persistence of sensorial activity makes it possible through suggestion to provoke hallucinations and develop automatic impulses at the will of the operator.

In the *lethargic* state, the similitude of profound sleep, there is complete analgesia of the skin and mucous surfaces accessible. The limbs are relaxed, and if raised fall slowly. The pupils are rolled upward, the eyes closed or half closed, while one sees an almost incessant quivering of the eyelids. The tendon reflexes are exaggerated and neuromuscular hyperexcitability is always present, though in varying degrees. This phenomenon, similar to the muscular contractions caused by the faradic current, may be produced by mechanical pressure alone, *e.g.*, by the touch of a pencil. Even muscular contractions more or less prolonged may result, which are readily resolved by stimulating antagonistic muscles.

The *induced somnambulistic* state corresponds more particularly to the condition of "magnetic sleep," so-called. It more nearly resembles the state of lethargy, yet there is no neuromuscular hyperexcitability as described above. Cutaneous analgesia is present, but at the same time there is a very remarkable hyperacuity of certain forms of sensibility of the skin, of the muscular sense and of some of the special senses, sight, hearing, and smell. It is easy through suggestion to call forth very complicated automatic actions which are induced manifestations peculiar to the state of artificial somnambulism, the active hypnotic condition (Charcot, "Œuvres Complètes," Tome ix.).

4. *Method of Suggestion.*—The method of inducing hypnosis by suggestion was practically, though not primarily, developed by the Nancy school, of which Lièbeault and Bernheim are the leaders. The idea of sleep is suggested to the subject's mind by every possible means, physical as well as mental. The subject is thoroughly reassured and placed in a comfortable position, so as to invite mental and physical repose. He is then told that he feels sleepy, that his eyelids are getting heavy, that he can scarcely keep awake, in fact he is going to sleep, etc., until a condition of semi-somnolence is established. This method has the merit of resulting in no danger to the subject, but it may require many séances before the successful end is gained.

The combination of the two methods of fixed attention with sleep suggestion is most commonly used in America, and with proper care will yield satisfactory results.

It is essential, however, to the successful therapeutic use of hypnotism that the subject be well trained as a hypnotic before suggestive treatment be given. It is just here, doubtless, that many physicians have failed while the professional hypnotizer has succeeded.

The following plan, suggested by A. E. Carpenter, merits attention and will lead to more successful results than the usual haphazard efforts for inducing hypnosis sufficiently deep for therapeutical or experimental purposes: No séance should last over long, lest undue fatigue result. The séance may be repeated, however, once or twice a day until the operator secures satisfactory results or concludes that his subject cannot be impressed. If, however, the state of semi-somnolence is developed, assure the subject that he cannot open his eyes, at the same time making a slight pressure upon the eyelids; and we find that the lids come open with more or less difficulty, or not at all. Later, the command alone is sufficient to prevent the lids being opened, and the patient becomes receptive to audible suggestion. Further suggestion both by touch and by command will affect other muscles; for example, the patient is told that he cannot open his hands when firmly clasped, pressure at the same time being made on the spine at the base of the skull. This is repeated until the experiment succeeds. Later the same condition may be produced by command alone, or again by the mere clasping of the hands together. In a similar manner control of all the muscles of the body may be secured. In turn the special senses may be educated in a similar way. The sense of feeling is most readily affected by suggestion and should be attempted first. It is important at the outset, when making suggestion, that the idea conveyed be not inconsistent with fact; for example, in a warm room it is wiser to suggest undue heat than extreme cold. After securing thorough control of the sense of feeling, subdue the sense of sight, employing the sense of feeling to aid in its control; for example, by making a suggestion which would involve both feeling and sight. In the same way one may gain control of the senses of hearing, taste, and smell, through means of others already subordinated. When once all the senses are under control of the operator, the therapeutic application of suggestion becomes simple. In some instances an impressionable subject becomes so susceptible to suggestion that hypnosis may be subjectively induced by mere concentration of attention—the auto-hypnotic state so called. Naturally it is of extreme importance to the success of the performance that the whole manner and tone of the operator convey assurance and never doubt of the result. Nor must it be forgotten that it is not impossible for the operator himself to become hypnotized by the exercise of too fixed attention upon the patient. Undoubtedly many operators have been deceived by apparent hypnotic phenomena through the reaction of suggestion upon their own minds. They see what they are "looking for."

The phenomena of hypnosis under the influence of suggestion are very variable, from the simple trance-like sleep to the complete control of the subject obtained in the condition of somnambulism. In the deeper phases the subject seems conscious only of the hypnotist and implicitly believes and follows out whatever suggestion is made. Upon awaking from the hypnotic state no conscious memory remains, yet a suggestion given during hypnosis may be implicitly obeyed at a period more or less remote. This is the post-hypnotic suggestion so called, and enables the operator to influence the subject after the hypnotic state has passed away. Thus in the treatment of dipsomania a suggestion is made during hypnosis that whenever he takes a dram he will be overcome with nausea. This associated idea is ever ready to meet the imperative habit and develops disgust and thus works a cure. This indirect or associated suggestion seems more powerful than the direct command to avoid drinking.

In the lighter phases of hypnosis the subject seems semi-conscious, but does not readily or at all respond to suggestions widely at variance with fact. He may not be able to open his eyes or shut his mouth, or raise a hand except at the will of the operator, but the assurance that his neuralgic pain is gone brings a smile or even breaks the spell. In the deeper or somnambulistic state no delusion suggested by the operator is too incredible. Every suggestion becomes an imperative idea, dominating feeling and emotion and controlling their physical expression. It is, however, a striking commentary upon the subjective nature of hypnosis that no suggestion of an idea foreign to the cognizance of the subject will gain representation. The fountain never rises above its source.

It will be readily understood how the symptoms of disease may be relieved; but that the disease itself may be arrested or cured is by no means so credible.

Its greatest service will be found in dealing with morbid psychological conditions, such as fixed ideas, morbid habits, sexual perversion, etc.

The various students of hypnotism have formulated certain rules regarding its use which it is well always to observe.

Public séances of hypnotism by professional hypnotizers should be forbidden by law.

Hypnosis should be employed only by physicians or psychologists familiar with the physiology and pathology of the mind.

It should never be induced without the consent of the subject or his legal guardian.

It should not be employed except in the presence of a third person.

Suggestions which are contrary to his moral nature should never be made.

After the employment of hypnosis the patient should always be awakened and left in a calm mood.

Regarding its medico-legal relations, it is pretty well established that in no case can a suggestion contrary to the moral nature of the subject succeed, the antagonistic instinct serving in turn as an overpowering negative suggestion.

Hypnosis is not a miraculous method of treatment to supplant other means, but rather a species of education of the mind which must be sufficiently repeated to secure permanence.

While it seems an easy way to relieve many forms of nervous trouble, in reality its permanent value is very limited. It is true that anæsthesia has been successfully induced by its means, and serious operations have been performed without pain. Medical literature teems with examples, but so few patients are sufficiently susceptible at first trial that it is of little practical value.

Hypnosis prolonged for hours, even days, has occasionally been of value in intractable forms of hysteria, and undoubtedly should be tried when other more rational measures have failed. But training of the hysteric to secure self-control is of more lasting benefit, and far more rational.

Among American neurologists the concurrent opinion is against the employment of hypnotism as a therapeutical measure. At the present time its greatest utility lies in the field of investigation of psychological phenomena rather than in the relief of pathological conditions.

Edward B. Angell.

HYPNOTICS are medicines used to induce sleep. Their utility depends upon their power of arresting the functions of the cerebrum for some time without endangering life or health.

Two views prevail as to their mode of action. According to the older one, they induce sleep by rendering the brain anæmic. The anæmia is supposed to result from a direct influence on the vaso-motor nerves, in consequence of which the cerebral vessels contract and thus diminish the quantity of blood circulating in the brain. This view was based on two facts frequently observed in experiments on animals whose brain had been exposed to view, viz., that the brain invariably *is* anæmic during natural sleep, and that it *becomes* anæmic during the artificial sleep induced by medicines. The brain presenting the same pale appearance in both forms of sleep, it was concluded that both are due to the same cause—a lessened flow of blood in the cerebrum.

But the theory that normal sleep is caused by anæmia of the brain is no longer tenable; for it has been found that the quantity of blood circulating in the brain, in the normal state of the organism, depends upon the activity of the brain, increasing in proportion to the exercise of the mental functions, and abating when the mind is quiescent. Little blood being required during the dormancy of the mental functions, the brain is comparatively bloodless, and, if open to inspection, presents a very pale appearance.

But if the brain is anæmic during normal sleep, will not cerebral anæmia, produced artificially, be followed by sleep? Of this there can be no doubt, since it has been shown experimentally that compression of the large arteries supplying the brain is speedily productive of unconsciousness. Hence, if hypnotics should cause contraction of the cerebral vessels and thus produce anæmia, sleep would necessarily ensue. But in recent experiments on animals, whose skulls had been trephined so that the brain could be inspected, it was found that hypnotics may induce deep sleep without in the least altering the quantity of blood circulating in the brain. Usually, when the sleep was prolonged, the brain gradually became pale and comparatively bloodless. The absence of cerebral anæmia during the early part of artificial sleep disproves the theory that hypnotics act indirectly through the vaso-motor system.

The fact that hypnotics may induce sleep without at first altering the quantity of blood in the brain gave rise to the more recent theory that they act directly on the cerebral cells. The nature of this action is unknown. Experiments performed by Binz seem to show that it may be attended by a very slight and transient coagulation of the protoplasm of the cerebral cells. That some decided, though not very durable, change of the cortical substance of the brain is produced is evident from the experiments of Albertoni, in which it was found that in dogs large doses of bromide of potassium reduced the excitability of the motor centres so much that electric irritation no longer caused epileptic convulsions. In some instances the brain was pale, but in others no diminution of the quantity of blood was observed, and hence the lessened excitability was not attributable to anæmia. Recently the theory has been advanced that natural sleep results from contraction of the protoplasmic processes of the cortical neurons.

The use of hypnotics is indicated, as a rule, when insomnia is continuous, and hence a source of danger; this sometimes occurs both in acute and in chronic diseases. Generally, normal sleep returns as soon as the causes of the insomnia are removed; but sometimes it is impossible to remove the causes, or sleeplessness persists after the removal of all apparent causes.

OPIUM and its preparations, in appropriate doses, usually induce sleep in one or two hours. In some cases of wakefulness, half a grain is followed by this effect; in others as much as two or three grains are required. The duration of the sleep varies from half an hour to six or eight hours, the variations depending upon the size of the dose, the time of administration, the nature of the cause of the insomnia, and the susceptibility of the patient. Given in the early part of the day, even large doses may act only for a short time; but in the evening, moderate doses often produce prolonged rest. When sleeplessness is caused by peripheral irritation of moderate intensity, small doses may induce continuous normal sleep; but when there exists intense pain, large doses are required, and sometimes must be repeated several times. Patients vary greatly in their susceptibility to the action of opium. In early childhood, especially in infancy, and in old age, moderate doses sometimes cause profound sleep bordering on coma.

The hypnotic action of opium is usually preceded and followed by numerous incidental effects. In many patients phenomena supervene, within half an hour after the ingestion of the medicine, which are due, perhaps, to a stimulant action on the brain—a free and copious flow of ideas, and an agreeable sense of well-being, followed soon by indifference to all external impressions and a feeling of fatigue. In very excitable patients, especially nervous females, there often occurs very notable mental excitement with hallucinations, and sometimes increased wakefulness and delirium. Some patients, on the contrary, particularly robust, strong men, do not manifest any of these phenomena, but are soon lost in a prolonged, quiet, and refreshing sleep.

The pulse, in from fifteen to thirty minutes after the hypnotic dose is taken, becomes accelerated by some six or eight beats in a minute, but falls again to its previous rate before sleep ensues. During the sleep, if the dose has not been excessive, it does not usually differ from its rate in normal sleep. Simultaneously with the acceleration of the pulse the skin becomes warm and moist, and the mouth dry.

After awaking the patient often complains of headache and fatigue, his appetite is diminished, and his bowels are constipated. Some patients suffer from nausea and vomiting, severe headache, and mental depression. If the hypnotic is taken repeatedly for some days, there often occur dysuria and itching of the skin.

During the sleep the patient may be readily wakened, unless the dose was excessive, when the sleep may be more profound. Then the pulse usually becomes slower, feeble, and sometimes irregular; the respirations diminish in frequency and depth, and may be stertorous; and the face becomes pale, moist, and cyanotic. The pupils are strongly contracted, unless the respiratory process is so depressed that asphyxia supervenes.

If continuously employed, opium soon loses its hypnotic action in ordinary doses.

Morphine.—The hypnotic action of the salts of morphine is identical with that of opium. In appropriate doses, administered internally, they induce sleep in about one hour. But this effect generally ensues sooner when they are injected into the subcutaneous connective tissue—often in from ten to thirty minutes.

The incidental phenomena do not differ notably from those produced by opium. Sometimes the pulse at first becomes slightly accelerated; more frequently it is not influenced at all, especially in healthy persons. In careful observations on healthy young men, Preisendörfer found no change, either in the frequency or in the tension of the pulse, after subcutaneous injections of quantities varying from one-sixth to one-half of a grain.

It is generally held that morphine produces less constipation than opium, but that it is more frequently followed by itching of the skin, dysuria, and, when administered by the mouth, nausea and vomiting.

In some patients subcutaneous injections of morphine speedily cause giddiness, headache, faintness, difficult breathing, trembling of the extremities, nausea, and vomiting.

Some persons experience only the useful hypnotic effect without any disagreeable phenomena, and can take a moderate dose—one-fourth of a grain of sulphate of morphine—night after night, for a considerable period, without loss of appetite, nausea, constipation, dysuria, or itching of the skin.

As a rule, opium or morphine may be used to induce sleep whenever insomnia endangers life or health, if no contraindications exist. They are preferable to other hypnotics when sleeplessness is caused by peripheral irritation, especially pain and cardiac dyspnœa. In such cases they act both indirectly and directly—indirectly, by removing or relieving the abnormal sensations which cause insomnia; and directly, by arresting the functional activity of the brain.

The utility of morphine in the wakefulness caused by cardiac dyspnœa has long been recognized. Allbutt and Ringer strongly recommend hypodermic injections as speedily effective in allaying the dyspnœa and inducing refreshing sleep. It is necessary, however, carefully to distinguish cardiac dyspnœa from the form of dyspnœa occurring in diseases of the air passages and lungs. According to the experiments of Filehne the immediate cause of cardiac dyspnœa is not an excess of venous blood, but a defect of arterial blood in the medulla oblongata. The medulla is excitable because it is anæmic. All heart diseases that markedly interfere with the circulation, such as valvular affections, dilatation, and pericardial effusion, cause the medulla oblongata to be insufficiently supplied with arterial blood, and hence render it excitable. The dyspnœa that results is wholly useless, as it cannot improve the heart's action; and is harmful in so far as it exhausts the strength. Morphine, therefore, should be employed in doses that will restore the breathing to the normal type. But it is otherwise when dyspnœa results in consequence of impeded arterialization of the blood in the lungs. The immediate cause of the dyspnœa is the excess of venous blood in the medulla oblongata. In consequence of the rapid breathing a larger quantity of blood becomes oxygenated in the lungs; the dyspnœa is, therefore, compensatory and absolutely necessary. Morphine, by diminishing the excitability of the respiratory centre, would increase the venosity of the blood and endanger life.

Opium and morphine are generally preferable to other hypnotics to relieve the sleeplessness occurring in the latter stage of febrile diseases, and depending upon an exhausted and anæmic condition of the brain.

Opium and morphine are contraindicated in wakefulness caused by cerebral hyperæmia. During the first stage of action they probably increase the amount of blood in the brain, and hence are apt to aggravate already existing hyperæmia. They are contraindicated in the wakefulness caused by dyspnœa, if the difficult and rapid breathing is necessary to compensate for some impediment to the interchange of gases in the lungs.

On account of the extreme susceptibility of children to the narcotic action of opium and morphine, these hypnotics are rarely employed to relieve insomnia during the first two or three years of life.

In all forms of chronic insomnia, if it be necessary to maintain a good state of nutrition, opium and morphine are contraindicated, unless it be found that they do not interfere with digestion.

The average dose of opium for adults is one grain, or an equivalent quantity of one of its preparations. As a rule, the dose should be given shortly before bedtime, and, if necessary, repeated in an hour. In cases of sleeplessness from pain and cardiac dyspnœa, smaller doses frequently induce sleep; but when these symptoms are very intense, it is often necessary to repeat the average dose several times.

The average dose of morphine is one-fourth of a grain. In many cases of wakefulness smaller doses suffice, if given at the usual bed-hour. The vomiting that sometimes results from hypnotic doses may usually be prevented by dissolving the salt in four to six drachms of water, and giving a teaspoonful of the solution at intervals of ten minutes.

Frequently morphine is administered by the hypodermic method in cases of insomnia due to pain or dyspnœa. Usually, at first not more than one-sixth of a grain is required to give relief and induce sleep. In the latter stage of acute diseases, when wakefulness is due to exhaustion, the hypodermic dose, as a rule, should not exceed from one-twelfth to one-eighth of a grain. In order to prevent as much as possible the disagreeable effects of morphine on the stomach and skin, it is customary to associate with it a very small quantity of atropine, about gr. $\frac{1}{100}$.

Codeine.—This alkaloid is a less powerful and certain hypnotic than morphine, but has been recommended as preferable to the latter when insomnia results from cough, rheumatic pains, and cancer. The quantity required to induce sleep varies greatly, sometimes this effect having resulted from one-fourth of a grain, and in other instances not from one grain repeated several times.

Small doses are usually not followed by severe after-effects, especially not by obstinate constipation. But large doses may cause nausea, vomiting, giddiness, headache, mental dulness, and tremor.

Codeine may be used as a hypnotic instead of morphine when the latter is not well borne, when constipation should be avoided, and when sleeplessness results from cough.

CHLORAL HYDRATE.—In doses of from 1 to 2 gm. (gr. xv.–xxx.) chloral hydrate usually induces sleep in from ten to thirty minutes. The sleep does not differ notably from natural sleep, the pupils being contracted and the pulse and respirations slow and regular. Generally it is quiet, dreamless, and refreshing, and continues for from two to eight hours. The patient may be readily awakened, but usually quickly falls asleep again.

As a rule, no disagreeable effects are noticeable either before or after the sleep. In irritable, weakly patients, however, a stage of excitement may precede the sleep, marked by injection of the face, restlessness, and hallucinations. These phenomena have been observed most frequently after small doses—eight to fifteen grains. After the sleep there may occur slight headache, with fatigue and somnolency. Usually the functions of the alimentary canal are not disturbed, the appetite being good and intestinal peristalsis normal. After prolonged use of chloral, especially if it is taken insufficiently diluted, symptoms of gastric catarrh become manifest. In weakly patients, and in those who have become much enfeebled by chronic diseases, ordinary hypnotic doses may notably depress the vascular system, render the heart's impulse very weak, and the pulse slow, very compressible, and irregular. These effects on the circulatory organs, due to a depressing or paralyzing action on the vaso-motor centre and the cardiac ganglia, become more marked the larger the dose. Hence, when very large quantities are taken—from one to several drachms—the heart's action becomes very feeble, and the pulse extremely weak. As a consequence, the circulation is so languid that the tissues are inadequately supplied with arterial blood, the temperature falls very low, and life may become extinct.

Although sleep usually ensues speedily from hypnotic doses of chloral, it is sometimes delayed for several hours. This is frequently observed after the continued use of the drug, the interval between ingestion and the supervention of sleep gradually becoming prolonged and marked by some excitement. As a rule, however, chloral in the same dose retains its power of inducing sleep for a long time.

After continued use of chloral very serious effects have been observed, such as erythematous blotches on the face and neck, bloating of the skin, papular eruptions, petechial spots, bedsores, an irritable pulse, severe attacks of dyspnœa, weakness of memory, dulness of intellect, paralysis of muscles, and general marasmus.

As a hypnotic, chloral hydrate presents the advantage of acting speedily and certainly, and not causing disagreeable after-effects. Its tendency to depress the vaso-motor centre and the heart makes it suitable in wakefulness associated with vascular excitement. It usually acts well in acute rheumatism, scarlatina, peritonitis, metritis, and febrile diseases generally, as well as in cerebral affections.

Chloral is preferable to other hypnotics when sleep should be speedily induced, as in cases of delirium tremens supervening soon after the receipt of a severe surgical injury. Under such circumstances it is sometimes the means of saving life.

In painful affections attended with vascular excitement, moderate doses of morphine are often associated with chloral in order to relieve the pain, as chloral alone has little analgesic power.

Chloral is a valuable hypnotic in the insomnia of children and the aged, as it does not, in appropriate doses, produce inordinate effects.

Chloral may be employed in all cases of insomnia, if no contraindications exist.

On account of its depressing action on the heart, it is contraindicated when this organ is enfeebled in consequence of fatty or other kinds of degeneration, valvular disease, dilatation, or malnutrition in the latter stages of prolonged fevers.

According to some observers, chloral sometimes produces delirium and great depression in diseases which interfere with the respiratory process, such as pneumonia, pleuritis, emphysema, and bronchitis.

Catarrhal and ulcerative affections of the stomach contraindicate the internal administration of chloral. In hysterical patients undue excitement, instead of refreshing sleep, frequently ensues from hypnotic doses.

On account of the varying susceptibility of different individuals to the action of chloral, it is prudent, when giving it to patients whose tolerance is unknown, not to prescribe more than 2 gm. (gr. xxx.), of which one-half may be taken at the usual bed-hour, and the other half, if necessary, an hour later. In states of great cerebral excitement, such as delirium tremens and acute mania, larger doses have been given with advantage—2 gm. (gr. xxx.), repeated several times, if necessary, at intervals of one hour.

As concentrated solutions disorder the stomach, it should always be well diluted with sweetened water or milk. ℞ Chloral hydratis, 2 gm. (ʒ ss.); aq. destill., 8 gm. (ʒ ij.). M. Sig.: One-half to be taken at bedtime, in a small cup of milk; and the other an hour later, if necessary. ℞ Chloral hydratis, 2 gm. (ʒ ss.); syr. aurantii, 15 gm. (℥ ss.); aq. menth. pip., 45 gm. (℥ iss.). M. Sig.: Two tablespoonfuls at bedtime; and the rest, if required, an hour later. In cases of insomnia dependent upon pain, a fourth of a grain of sulphate of morphine may be added to either of the above formulæ.

If chloral be required as a hypnotic in cases of severe disease of the stomach, it may be administered by rectal injection. Subcutaneous injections of chloral are inappropriate, except perhaps in strychnine poisoning, on account of the severe irritation which results.

BUTYL CHLORAL HYDRATE.—This substance acts like chloral hydrate, inducing quiet and refreshing sleep in from ten to thirty minutes. During the sleep circulation and respiration are normal. It is held that butyl chloral does not depress the vaso-motor centre and the heart as much as chloral hydrate, but that it exerts a more decided anæsthetic effect on the trigeminal nerve.

As a hypnotic it has been recommended in the insomnia associated with diseases of the heart, and with neuralgia of the fifth nerve.

The ordinary dose varies from ten to forty grains. It is best administered in solution with glycerin. ℞ Butyl chloral hydratis, 4 gm. (ʒ i.); glycerini, 10 gm. (ʒ iiss.); aq. destill. ad 60 gm. (℥ ij.). M. Sig.: A tablespoonful every half-hour until sleep ensues.

CHLORALAMIDE, or CHLORAL-FORMAMIDE.—Chloralamide was introduced in 1889 by von Mering as a substitute for chloral in cases of insomnia in which the influence of chloral on the organs of circulation should be avoided. He supposed that the formamide, contained in chloralamide, would effectually prevent the depressing action of chloral.

The experiments made upon animals yielded somewhat discordant results, not as to the influence of chloralamide on the brain, but as to its action on the organs of circulation and respiration. Von Mering, Zuntz, and Kny noticed no fall of blood pressure in rabbits under the influence of hypnotic doses of chloralamide. Langgaard, on the contrary, observed after moderate non-toxic doses decided lowering of blood pressure, although this effect supervened more slowly than after chloral. These contradictory results were probably due to variation in the rate of decomposition of the chloralamide in the different animals subjected to experiment.

Upon man chloralamide acts like chloral, except that it produces sleep less rapidly and less certainly. As a rule after doses of 2 to 3 gm. (gr. xxx.–xlv.) sleep ensues in half an hour and continues for from five to eight hours. During the sleep, the functions of circulation and respiration are performed as vigorously as in normal sleep. After awaking the patient presents no disagreeable effects.

Numerous deviations, however, from this ordinary action have been observed, depending chiefly upon the causes of the insomnia. Thus, in cases of intense excitement of the brain, of severe pain, of harassing cough, and of high fever, doses of 2 to 3 gm. have failed to produce sleep, and sometimes even 4 gm. (ʒ i.) have been ineffectual. Often, even when the causes of insomnia were not intense, sleep did not supervene before an hour, sometimes two hours, and in rare instances even three hours. In some cases of heart disease, especially in valvular disease with imperfect compensation, a very decided depression of the circulation has been observed. So, too, in typhoid fever a very unfavorable effect upon the pulse was noticed after 2 gm. (ʒ ss.) given in divided doses. The temperature was always found lowered from one-half to one and one-half degrees.

Generally, after-effects do not occur, or they are very trivial, consisting of headache, slight giddiness, a feeling of fatigue, and skin eruptions.

From the above, it is evident that chloralamide closely resembles chloral in action, but that it induces sleep more slowly and less certainly, and that it is less apt to depress the circulation. The differences seem to be due to slow and gradual liberation of chloral in the blood, although it is not improbable that the presence of the formate of ammonium may somewhat modify the action of the chloral on the organs of circulation and respiration. The variations in the rapidity of action doubtless result from differences in the rate of decomposition in the blood of different persons.

Chloralamide is a suitable hypnotic in insomnia not caused by intense excitement of the brain, very severe pain, or extreme dyspnœa. When severe pain causes insomnia, chloralamide alone is not very efficient, but it acts well if given together with a moderate quantity of morphine. In the insomnia associated with mild nervous excitement, with neurasthenia, and with somatic diseases in general, moderate doses, 2 to 3 gm. (ʒ ss.–gr. xlv.), are usually effectual. Such moderate doses having frequently failed in cases of intense mental excitement and severe pain, larger doses, as much as 4 gm. (ʒ i.), have been recommended; but it should be recollected that such large doses may cause dangerous depression. Even moderate doses should not be given in cases of heart disease, if the heart's action be very feeble, or if symptoms of inadequate compensation be present. In no case should the dose be larger than the corresponding dose of chloral, 3 gm. of chloralamide being equivalent in action to 2 gm. of chloral. The following are convenient formulæ: ℞ Chloral. formamide, 4 gm. (ʒ i.); aq. dest., 75 gm. (℥ iiss.); acid. hydrochlor. dil., gtt. v.; syr. aurantii, 15 gm. (℥ ss.). M. S.: One-half to be taken at bedtime, and, if necessary, a tablespoonful every hour till sleep ensues. ℞ Chloral. formamid., 4 gm. (ʒ i.); Spir. frumenti, syr. rubi idæi, āā 15 gm. (℥ ss.). M. S.: One tablespoonful at bedtime.

Sulphonal.—This remedy was recommended as an efficient hypnotic by Kast in 1888. He had tried it in numerous cases of insomnia, and nearly invariably quiet and deep sleep ensued and lasted for from five to eight hours. During the sleep the functions of circulation and respiration were somewhat slowed as in ordinary sleep, but no deviation from the normal could be observed. After awaking the patients presented no after-effects, except that in a few instances some fatigue and languor existed on the following day. After the publication of Kast's observations, sulphonal was very extensively used. It proved very effective in nervous sleeplessness and generally also when the insomnia was caused by disease of the brain, disordered circulation, and neuralgia. It was not so successful in delirium tremens and often failed when the sleeplessness was caused by severe cough, dyspnœa, or intense pain, though when given together with small doses of morphine, it also acted well in the latter conditions. Usually no disagreeable effects were observed during or after its action, or at most some languor and drowsiness on the following day. In a few instances, especially when the doses were large, and after repeated administration of moderate doses, there followed headache, vertigo, tinnitus aurium, and staggering.

Further experience with sulphonal caused its use to become much restricted, as it was found, in cases requiring its administration for a long time, frequently to produce severe toxic effects and in a few instances death. Bad effects were observed in some cases after doses of 1 to 2 gm. given daily for some weeks or months, though in most cases of prolonged administration no notable disorder resulted. In many cases the urine presented an intensely red color, from the presence of hæmatoporphyrin, and its quantity was notably lessened. Besides great general debility, there were observed anorexia, severe pain in the epigastrium and right hypochondrium, vomiting, obstinate constipation, sometimes diarrhœa, headache, drowsiness, disorders of sight, diminution of reflexes, staggering gait, ascending paralysis and coma.

The supervention of toxic effects is more apt to occur in weakly, anæmic, old patients, and those having notable disorder of the alimentary canal, such as gastric and intestinal catarrh and constipation.

The dose of sulphonal is 1 or 2 gm. dissolved in about six or eight ounces of hot liquid—water, milk, bouillon, soup, tea—and given a short time before retiring. In most cases of insomnia it is best to begin with 1 gm.; if this should not have the desired effect, the next dose may be 1.3 gm. (gr. xx.); and, if necessary, the subsequent doses may be gradually increased to 2 gm. (gr. xxx.). Should this dose not act, some other hypnotic should be resorted to. Under no circumstances should sulphonal be given every night for any length of time.

Trional is closely allied to sulphonal in chemical constitution, physical properties, and physiological action. It is somewhat more soluble, acts more rapidly and certainly, and is less frequently followed by disagreeable and toxic effects when continually used for months. Hence it is now very extensively used and in many asylums has entirely supplanted sulphonal. Like sulphonal it produces during the sleep no notable aberrations in the organic functions of respiration and circulation. The sleep is sound and refreshing, and as a rule is not followed by any obvious disorder, except in rare cases, generally feeble patients, who may be somewhat drowsy or complain of headache and giddiness. In some instances the long-continued use of trional has been followed by gastric disorder, vomiting, constipation, delayed hypnotic action, oliguria, and hæmatoporphyrinuria.

The dose of trional is from 1 to 2 gm. (gr. xv.–xxx.). If 1 gm. (gr. xv.) should fail to produce satisfactory sleep, the next dose should be 1.3 gm. (gr. xx.). It will rarely be necessary to give more than 1.5 gm. (gr. xxiiss.). The dose found necessary should be given in six or eight ounces of hot liquid just before retiring, and should be repeated not oftener than every other night. If a hypnotic be required in the intermediate nights, chloral, chloralamide, or amylene hydrate may be used.

It is not necessary to increase the dose of trional; on the contrary, often the dose may be somewhat diminished.

Paraldehyde.—Vincenz Cervello, in 1882, recommended this substance as an efficient and safe hypnotic, which might be substituted for chloral hydrate in all cases in which depression of the heart should be avoided. In numerous experiments on animals and human beings he had found that it induced quiet, prolonged sleep, without altering the functions of circulation and respiration, and without causing excitement or disagreeable after-effects.

Since recommended by Cervello, paraldehyde has been tested by numerous careful observers. It was found, as a rule, to act satisfactorily in mania, delirium tremens, hysteria, hypochondriasis, and other ordinary diseases. In cases of cardiac disease, in which the heart's action was very weak, it caused no notable depression. The observations thus far made have confirmed the results obtained by Cervello, that paraldehyde is a powerful hypnotic which does not unduly act on the heart or respiratory centre, and that it should be preferred to chloral hydrate in all cases of decided cardiac weakness.

It cannot be substituted for morphine in cases of insomnia caused by pain, as it seems to possess no marked analgesic action.

The dose required for hypnotic purposes varies greatly with individual susceptibility. Cervello found that 1 gm. sometimes had a quieting effect in women, while 4 gm. often failed to induce sleep in strong men. From experiments on animals he supposed that the hypnotic dose might be three times as large as that of chloral hydrate, and from his trials on healthy men and patients he concluded that 10 gm., administered in divided doses, might be given to adults without causing any notable disorder.

Being very acrid, paraldehyde is contraindicated in irritable states of the throat and stomach.

If administered in a concentrated form, it produces a strong sensation of burning in the mouth. Cervello gave it in very dilute solution in sweetened water, and observed that solutions containing more than three per cent. have a disagreeably pungent taste.

As a rule, it is necessary to give at least fifty minims to induce sleep, and in most cases this quantity must be repeated once or twice at intervals of half an hour or an hour.

At the temperature of 59° F. paraldehyde is dissolved in eight parts of water, but it is less soluble at higher temperatures. It may be prescribed in concentrated solution; but each dose should be diluted with about two and a half ounces of water before ingestion. ℞ Paraldehyd., 10 gm. (ʒ iiss.); syr. aurantii, 15 gm. (℥ ss.); aq. destill., 75 gm. (℥ iiss.). M. Sig.: Two tablespoonfuls at bedtime; afterward, if necessary, one tablespoonful every half-hour until sleep ensues.

Hodgson recommends the following formula: ℞ Pulv. trag. co., 4 gm. (ʒ i.); syr. aurantii, 15 gm. (℥ ss.); paraldehyd., 4 gm. (ʒ i.); sp. chloroform., ♏ xv.; aquæ, q.s. ad 90 gm. (℥ iij.). M.

Amylene Hydrate was recommended as a hypnotic by von Mering in 1887. In experiments upon animals he had found that moderate doses act chiefly on the cerebrum, producing sleep for hours without notably modifying respiration or circulation, and that large doses affect also the spinal cord and the medulla oblongata, arresting the reflexes, breathing, and heart action.

Von Mering administered it to sixty patients afflicted with insomnia. After doses of 3 to 6 gm., sleep ensued within half an hour and continued for from six to eight hours. Only four times was the hypnotic action unsatisfactory. No disagreeable incidental effects occurred, and only one patient complained on the next morning of slight headache. When the sleeplessness was caused by pain, amylene hydrate did not act well; but the simultaneous administration of a small quantity of morphine rendered the action satisfactory. Von Mering considered 2 gm. of amylene hydrate equivalent to 1 gm. of chloral hydrate and to 3 gm. of paraldehyde.

Since von Mering's recommendation of amylene hydrate it has been frequently used especially in asylums and has been found safe and efficient; but owing to its disagreeable odor and taste and occasional untoward action, it can be used only to a limited extent in private practise. Some patients refuse to take it on account of its pungency; others complain, after taking it for some time, of discomfort after eating—a disturbance of digestion that may in part be due to irritation but more to interference with the action of the pepsin. In a few instances it has caused effects resembling alcoholic intoxication before sleep ensued, and after the sleep nausea, headache, and giddiness. In some cases it accelerates, in others slows, the heart's action and renders it somewhat irregular. In some instances its action is prolonged, the patient being drowsy on the next day. Sometimes also it fails to act efficiently after it has been given five or six times. But notwithstanding these defects, amylene hydrate is an excellent hypnotic adapted to occasional use in cases of insomnia requiring the prolonged use of hypnotics.

The dose of amylene hydrate is 2 to 4 gm. (ʒ ss.–ʒ i.) mixed with water and syrup or liquorice. ℞ Amyleni hydrat., 6 gm. (ʒ iss.); Aq. dest., 60 gm. (℥ ij.); Extr. glycyrrh., 10 gm. (ʒ iiss.). M. S.: One-half to be taken before retiring. ℞ Amyleni hydrat., 6 gm. (ʒ iss.); Aq. aurantii florum, 45 gm. (℥ iss.); Syr. aurantii, 30 gm. (℥ i.). M. S.: One-half to be taken at bedtime.

Bromides.—The bromides of potassium, sodium, lithium, and calcium, and hydrobromic acid, are efficient hypnotics in some kinds of insomnia, although in the normal state of the organism, administered during the daytime, they do not induce sleep except in very large doses. Their hypnotic action is not attended or followed by disagreeable effects, unless they are given in a too concentrated form or their use is continued very long. Administered when the stomach is empty, they quickly produce disorder of digestion, unless diluted with a large quantity of water. When used continuously they often cause eruptions on the skin, catarrh of the air passages, fetor of the breath, pallor of the face, emaciation, debility, depression of the sexual function, and dulness of the intellect with weakness of memory. But these effects speedily subside when their use is discontinued.

The bromide of potassium in large doses diminishes the frequency and force of the pulse and lowers the temperature. In healthy persons Krosz found the pulse diminished in frequency from eleven to twenty-two beats in the minute after doses of 10 gm., and as much as thirty beats after 15 gm. The pulse was weak and sometimes irregular. The temperature fell from 0.5° to 0.8° C. after doses of 10 gm., and 1.2° C. after 15 gm. The maximum effect on the pulse and temperature occurred between the second and third hour after the ingestion of the salt. Bromide of sodium in large doses did not lessen the frequency of the pulse nor lower the temperature.

The bromides are preferable to other hypnotics in the wakefulness depending on abnormal excitability of the brain. They are usually efficacious in the early stage of delirium tremens, in hysteria, insanity, hypochondriasis, and the night terrors of children. As they are harmless, they should be preferred in the insomnia caused by severe mental strain, intense emotions, and worry.

Bromide of potassium frequently induces sleep in febrile affections. As long as the temperature is abnormally elevated, and the pulse strong, it is more suitable than other bromides. But in the latter stages, when the heart's action is notably weakened, bromide of sodium is the more eligible salt. In all cases of chronic sleeplessness in which depression should be avoided, bromide of sodium should be preferred to the bromide of potassium.

The bromides are usually given in doses of from twenty to forty grains, shortly before bedtime, and repeated at intervals of two hours if necessary. In many cases of chronic wakefulness it is better to give fifteen or twenty grains soon after each meal, and before retiring. Each dose should be diluted with several ounces of water. ℞ Potassii brom., 8 to 12 gm. (ʒ ij.–iij.); Sacch. albi, 4 gm. (ʒ i.). M. Div. in part. æq. No. vi. Sig.: One powder in a wineglassful of water at bedtime. ℞ Sodii brom., 15 gm. (℥ ss.); Aq. menth. pip., 45 gm. (℥ iss.). M. Sig.: One teaspoonful at bedtime in a wineglassful of water; repeat the dose every two hours if necessary.

Hyoscyamus.—The preparations of hyoscyamus, in large doses, sometimes induce sleep; but on account of the uncertainty of their action and the disagreeable incidental effects, they are rarely employed to relieve insomnia in adults. They are frequently used to quiet the restlessness incident to the diseases of children, who tolerate larger doses proportionally than adults. Recently the alkaloids obtained from hyoscyamus have been recommended as powerful hypnotics in some forms of insomnia.

Hyoscyamine has been used chiefly in excited conditions of the brain, such as delirium tremens and mania. Generally, doses of one-sixteenth to one-eighth of a grain suffice to induce sleep of several hours' duration; but frequently larger doses are necessary—from one-sixth to one grain. Sleep follows very rapidly after the largest dose, often in fifteen minutes; it becomes very deep, may continue ten or twelve hours, and is sometimes attended by marked prostration.

The incidental effects consist chiefly of hallucinations, delirium, dryness of the mouth and throat, marked acceleration of the pulse and respirations, and great dilatation of the pupils.

Ringer found small doses of hyoscyamine inefficient in delirium tremens; larger doses produced many hours' sleep, but without improving the delirium and general condition of the patients.

Hyoscine Hydrobromate (Scopolamine hydrobromate).—This salt has lately been recommended as a very efficient hypnotic. In doses ranging from gr. $\frac{1}{120}$ to $\frac{1}{70}$ it promptly induces sleep, which lasts from one to four hours if the medicine is given in the daytime, and from six to ten hours if given at night. Wetherill found that even smaller doses, gr. $\frac{1}{200}$, frequently produced prolonged rest in cases of insomnia. It is rarely necessary to repeat the dose, or rapidly to increase it.

The following incidental effects have been observed: slowing of the pulse and respiration, slight elevation of temperature, hoarseness, suffusion of the face, sweating, dilatation of the pupils, relaxation of the muscles, impaired co-ordination, and a sense of fulness in the head and of wretchedness.

Occasionally moderate doses are followed by nausea, vomiting, anorexia, dysuria, syncope, with small, rapid, irregular pulse, and with symptoms of partial paralysis of the pneumogastrics (Wetherill).

Hyoscine has been used in the insomnia of acute delirious mania, of agitated melancholia, neurasthenia, chronic mental disorder, the morphine habit, alcoholism, and in confirmed cases of insomnia from unascertained causes. As a rule, it promptly induced quiet and prolonged sleep.

For internal use the following formula is convenient: ℞ Hyoscin. hydrobr., 0.01 gm. (gr. $\frac{1}{6}$); Aq. dest., 80 gm. (ʒ xx.); Syr. aurantii, 20 gm. (ʒ v.). M. S.: One teaspoonful once or twice daily.

Cannabis Indica.—Cannabis indica has been used as a substitute for opiates when the latter do not agree with the patient, and in cases of acute and chronic mental derangement. The susceptibility of different individuals to its hypnotic action varies greatly. Fronmüller, who administered it in 1,000 cases, found that it succeeded completely in 530, incompletely in 215, and had little or no effect in 255. In careful experiments Preisendörfer found that doses of one grain and a half of an alcoholic extract sometimes acted well, but in other cases had no effect. Larger doses, in no case exceeding five grains, usually produced more or less deep sleep.

Generally, hypnotic doses of cannabis indica produce decided incidental effects, such as giddiness, headache, hallucinations, delirium, slight redness of the face and conjunctiva, dilatation of the pupils, and brilliancy of the eyes. Very large doses often cause intense headache, nausea, and vomiting. In the experiments of Preisendörfer marked alterations of the circulation were observed. Two or three hours after the medicine had been given there occurred palpitation of the heart, with general relaxation of the arterial tension and increase of pulse rate from eleven to twenty-two, sometimes even forty, beats per minute. Sleep usually ensued at the time when the changes in the circulation began.

The hypnotic action of cannabis indica seems to be increased by bromide of potassium. As a result of experiments Clousten found that forty-five minims of the tincture of cannabis indica, with forty-five grains of bromide of potassium, were fully equivalent to a drachm of laudanum as a means of allaying maniacal excitement.

Hedonal, according to recent reports, seems to be a useful hypnotic in light forms of sleeplessness. In appropriate doses it usually induces sleep in about half an hour, though sometimes its action is delayed for one or two hours. The sleep may continue for from two to eight or nine hours, depending upon the size of the dose and the condition of the patient. After some time, several days or weeks, the dose must be somewhat increased to obtain the hypnotic effect. Usually no incidental effects are observed either during or after the sleep—the pulse, the breathing, and the temperature not deviating from the normal. In a few instances, on the day following the sleep, complaint is made of headache and giddiness.

The dose of hedonal is from 2 to 3 gm. (gr. xxx.–xlv.) given as a powder, which may be placed upon the tongue and swallowed with some cold water. It is supposed that 2 gm. act as efficiently as 1 gm. of trional and 2 gm. of chloralamide.

Dormiol has been found to produce sleep in about half an hour, which may continue for from one to ten hours, but on the average continues five hours. No notable depression of the functions of circulation and respiration occurred. Usually the doses given varied from 1 to 4 gm. of a ten-per-cent. solution. It was better to give one large dose than several small doses at intervals. Dormiol is held by some observers to be quick, safe, and sure in action.

Chloretone causes sleep in about half an hour, and this effect may continue for from one to twelve hours, the average being about four and a half hours. After large doses the pulse becomes depressed both in volume and in frequency. The breathing also becomes lessened in depth and volume, and the temperature lowered.

In experiments on warm-blooded animals it was found that chloretone in hypnotic doses diminishes the frequency and volume of the inspirations; depresses the vaso-motor centres and dilates the blood-vessels, thus lowering blood pressure, and also depresses the heart and lowers temperature.

Some recent writers, however, state that they have obtained good results from the employment of this remedy in the persistent insomnia of the aged, and in cardiac disease with renal complication and high arterial tension. In some cases sleep ensued after doses of 1.3 to 1.6 gm., but in most cases it was necessary to repeat this dose once or twice.

Chloralose acts as a hypnotic in smaller doses than chloral, but seems also to be more toxic and less certain. In a child the small dose of 0.2 gm. caused trembling of the hands and arms, and severe dyspnœa. Very grave symptoms have followed 0.3 gm.—coma, oscillatory movements of the head and the arms, and Cheyne-Stokes breathing.

It is given in doses of 0.2 to 0.3 gm. in capsule.

Samuel Nickles.

HYPODERMATIC MEDICATION.—The hypodermatic method of administering drugs, now so commonly employed, was first introduced by Dr. Alexander Wood, of Edinburgh, in 1843. It was gradually evolved, by the patient labors of numerous observers, from the endermic or endermatic mode of using certain soluble remedies formerly much in vogue, and, as the term clearly indicates, consists in the injection of solutions of suitable medicaments under the skin by means of a small syringe specially adapted to this purpose.

To insure success, care should be taken in the choice of the syringe. The essential qualities are, uniformity of calibre of the barrel, a properly fitting piston, and a sharp needle attached to the nozzle by means of a water-tight joint. These instruments are now made of glass, celluloid, hard rubber, and metal.

Since the earlier days in the history of this subject, important improvements have been wrought in the construction of hypodermatic syringes, so that of late years they have been offered in great variety; and manufacturers have displayed much enterprise and ingenuity in bringing them to the present state of completeness. Excellent instruments may now be readily obtained at very moderate cost.

The original syringes, and those of inferior quality still made, consist of a glass barrel with a metal or hard-rubber cap at each end.

This kind of instrument is not to be recommended. It is frail; the mountings, of metal or hard rubber, are liable to be separated from the barrel by very slight force; it is apt to become leaky, and the diameter of the glass tubing is rarely uniform throughout its length; but even in this class of instruments, some superior workmanship is now shown in the best specimens offered by dealers.

A decided improvement upon this make is illustrated by Fig. 2772. The glass barrel is enclosed in a fenestrated, sometimes a double fenestrated, metal sheath, which reveals the contents of the syringe when charged, and renders an otherwise weak instrument sufficiently strong for ordinary use. It is easily taken apart for cleaning, and to those who prefer the glass barrel it is recommended. Nevertheless, it is open to other objections urged against glass syringes. Unequal diameter of the cylinder and likelihood of leakage are the principal defects.

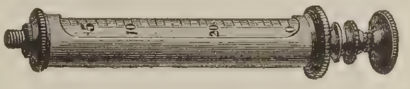

FIG. 2772.

Neither the celluloid nor the hard-rubber syringes have given entire satisfaction, and the specimens usually found in the market cannot be indorsed as trustworthy or desirable instruments.

The metal syringes are to be preferred to all others on account of their superior strength and durability, the even diameter of the bored cylinders, freedom from leaks, and compactness of construction. The metals used in their manufacture are German silver or brass—plated inside and outside with nickel—pure silver, and gold.

Fig. 2773 illustrates an instrument which meets fully the demands for a first-rate hypodermatic syringe. It has a nickel-plated German silver barrel, which is not corroded or injuriously affected by any solution which it is proper to inject into the tissues.

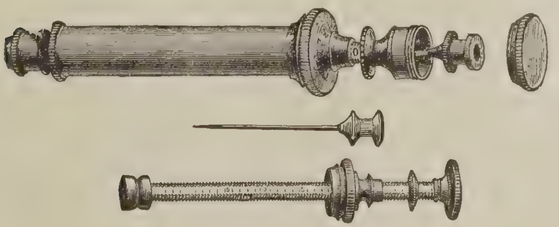

FIG. 2773.

The minim scale, in this instrument, is placed upon the semi-cylindrical piston rod, which is made hollow to receive the needle, and is provided with a screw-thread and traverse nut, designated to regulate, when set, the extent of downward movement of the piston. A cap should be screwed upon the nozzle when the needle is removed. If desired, a drop or two of water may be put in the cap to prevent inconvenient drying of the packing.

These syringes require no case for their protection, but may simply be slipped into a chamois-skin pouch and carried, without injury, in the pocket. More recently the leather-packed piston has been superseded by a solid metal plunger, which is so accurately adjusted to the barrel that no packing is required. Thus the annoyance of a dry and consequently an insufficient packing is obviated and a thoroughly aseptic instrument may be insured (see Fig. 2774).

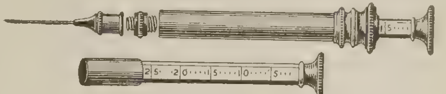

FIG. 2774.

It is prudent to be provided always with an extra needle, which may be enclosed and held by a screw-thread, in a small metal sheath, furnished by instrument-makers for this purpose.

The gold and silver syringes are not superior in practical utility to the instrument above described, and are unnecessarily expensive. The syringes provided for diphtheria antitoxin are similar in construction to the ordinary instrument, but are considerably larger. The packing of the piston is made of rubber and by a simple but ingenious mechanical device may be tightened at will. The syringes used for subarachnoid injections are substantially the same as the antitoxin syringes.

The needles for hypodermatic syringes are usually made of steel, plated with gold or nickel. Some advantages are claimed for gold or platinum needles. The needles are attached to the nozzle of the syringe by a screw or slide joint. The former is the more convenient style. A fine wire should be passed through the needle when it is not in use, to prevent occlusion of the calibre, either by the deposit of crystals from any solution that may have been employed, or by the accumulation of rust. The needles ought to be of small size, with large relative calibre, and it is desirable to have the tips strengthened at the junction with the sockets. The points should be lancet-shaped and free from any groove, depression, or shoulder-like projection.

The use of these instruments requires no special skill, though the dextrous performance of the little operation materially diminishes the discomfort of the procedure to the patient. The skin may be pinched up between the thumb and forefinger of the left hand, while the needle, held perpendicularly to the surface, is thrust rapidly through it. After penetration, the point of the needle should be passed obliquely to the desired depth into the areolar tissue, and the contents of the syringe slowly discharged. The operator, before making the puncture, must be careful to expel all air from the syringe by inverting the instrument, and at the same time depressing the piston sufficiently to cause a drop of the contained solution to appear at the point of the needle. It is scarcely necessary to urge the importance of rinsing out the barrel and of thoroughly cleansing the needle, immediately after using the instrument.

The injection may be made under the skin in almost any portion of the body; but the neighborhood of large vessels and nerves, bony prominences, and specially sensitive or inflamed regions should be avoided. The places ordinarily selected are the arm, near the insertion of the deltoid muscle, and the outer surface of the thigh. The rapidity with which absorption takes place is regulated somewhat by the vascularity of the part into which the injection is made. It is stated by some writers that a prompter effect may be expected from injections into the inner aspect of the limbs, or into the pectoral region, than from similar injections into the outside of the limbs or into the back. If this difference really exists, it must be so slight that it is scarcely worthy of serious consideration.

The injections may be superficial, into the subcutaneous areolar tissue merely, or they may be deep, into the body of a muscle, or, as has been recommended in some obstinate cases of sciatic neuralgia, a concentrated solution of morphine may be forced into the very substance of the nerve itself. Injections are sometimes made into diseased tissues and into abnormal growths. Intravenous and intraspinous or subarachnoid injections are also practised, but a consideration of these procedures, and of hypodermatic alimentation, is incompatible with the scope of this article.

The remedies most commonly used hypodermatically are morphine, codeine, atropine, hyoscine, hyoscyamine, strychnine, eserine, pilocarpine, caffeine, cocaine, apomorphine, ergotin, quinine, arsenic, mercury, chloral, digitaline, nitroglycerin, alcohol, and ether.

Morphine thus employed has a wide range of usefulness, and, on account of its power to allay pain, is far more frequently given hypodermatically than any other drug. The sulphate is the salt generally used. It makes a solution which is in every respect well adapted to subcutaneous administration. The ordinary dose is from one-sixth to one-fourth of a grain.

Codeine is used to meet the same indications and is sometimes a desirable substitute for morphine. It is not so likely to nauseate or to constipate, though as an anodyne it is not so trustworthy. The usual dose of either the phosphate or the sulphate is from one-half to one grain.

Atropine, in minute doses, is often combined with morphine, as it is capable of correcting, in some instances, the occasional unpleasant after-effects of the opiate when taken alone, besides possessing valuable therapeutic properties of its own. As an antidote to opium in toxic quantity it is superior to any other drug. The dose ranges from gr. $\frac{1}{150}$ to gr. $\frac{1}{60}$. Duboisine has been recommended as an advantageous substitute for atropine in about the same doses.

Hyoscine is a most valuable cerebral and spinal sedative and hypnotic in doses of gr. $\frac{1}{100}$ of the hydrobromate. It may be administered alone or combined with other anodyne and narcotic drugs. In combination with codeine its hypnotic effect in cases of cerebral excitement is most gratifying.

Hyoscyamine is closely allied in its action to atropine, but it has been found peculiarly effective in allaying maniacal excitement. The usual hypodermatic dose is gr. $\frac{1}{60}$. It should be cautiously administered at first. Testimony is not lacking of its value in various forms of motor excitement—as muscular tremor, laryngismus, hiccough, etc.

Strychnine produces more decided, and often more satisfactory, results when injected subcutaneously. A simple aqueous solution of the sulphate answers this purpose well. One grain to the ounce of water makes a convenient solution, which will keep without change for a considerable time. Fifteen drops—representing gr. $\frac{1}{32}$ —gradually increased when required,—is a proper initial dose.

Eserine, the active principle of calabar bean, acts more promptly when given hypodermatically than when administered by the stomach. The dose of the sulphate or muriate is from gr. $\frac{1}{100}$ to gr. $\frac{1}{50}$. In effect, it diminishes the reflex excitability of the spinal cord.

Pilocarpine is administered in doses of from one-eighth to one-quarter or one-half of a grain. The nitrate is the salt most commonly employed. It is freely soluble in water, and acts, when used hypodermatically, with great promptness.

Caffeine—the sodio-benzoate—may be exhibited in one-grain doses in conditions of mental and physical depression, for nervous headaches—especially for such as are dependent upon the omission of the accustomed cup of coffee—and in addition to atropine in cases of opium poisoning. It has also been used with some success in the treatment of neuralgia.

The hydrochlorate of cocaine is used hypodermatically mainly for its local anæsthetic effect. Its use is not free from danger. Excessive depression of the circulation sometimes follows its administration. The dose is from one-eighth to one-half of a grain, dissolved in water. The latter quantity has produced alarming symptoms, but is ordinarily safe, especially when preceded by generous alcoholic stimulation. It seems, however, that in smaller doses it reduces the frequency, but increases the force, of the pulse. More or less nausea may be experienced during its action. The extent of its anæsthetic influence is very limited, probably including only the absorbing tissues which may be brought into immediate contact with the solution. It is more than likely that the drug supplied by the trade is of variable strength. Herein lies a danger that should be watched.

Apomorphine is serviceable in conditions requiring a prompt emetic, and when, from unconsciousness or from some other circumstance, deglutition is rendered impracticable. It is conspicuously useful in some cases of narcotic poisoning. In consequence, however, of its depressing influence upon the system it should be used with caution, more especially in cases of profound narcotization, in which the respiratory and cardiac movements are feeble. The usual dose is one-tenth of a grain for adults.

Ergotin is given subcutaneously in doses of from two to five or ten grains, or even in larger quantity in cases of extreme urgency. One drachm of water will dissolve twenty grains of ergotin—which, in fact, is only an aqueous extract of ergot. A more concentrated solution may be made by rubbing up the purified extract with distilled water until one minim represents one grain. It should be carefully filtered to remove all solid particles. One-half grain of carbolic acid added to each ounce of the solution will prevent destructive changes, which, without it, will take place very rapidly. In the absence of the aqueous extract the fluid extract may be used. Ergotin injected under the skin is beyond doubt a most potent remedy in hæmoptysis, hæmatemesis, metrorrhagia, and, indeed, in many forms of hemorrhage beyond the reach of surgical control. It is valuable also in congestions of the brain and spinal cord, in the early stages of meningitis, and in a number of uterine and other disorders. Sclerotinic acid has been prescribed as a substitute but it does not represent ergot.

The sulphate of quinine—the salt of quinine commonly prescribed in this country—requires for its solution seven hundred and forty parts of water, which fact is an insuperable obstacle to its satisfactory hypodermatic administration. It has been proposed to dissolve the disulphate of quinine in water by means of heat and of dilute sulphuric acid—two minims to the grain—so that one drachm of the solution would contain six grains of the quinine. The solution is to be filtered immediately and a few drops of carbolic acid added to insure sterility.

The official bisulphate of quinine, as commonly supplied, while freely soluble in water—one part in ten—contains an excess of acid, and, consequently, like the foregoing, is very irritating to the tissues.

The kinate of quinine has been used, and, although it is dissolved by four parts of water to one of the salt, it is not free from objections.

The hydrobromate of quinine is soluble in the proportion of one part to sixteen of water at a temperature of 59° F. Heat, or the addition of a little alcohol, increases its solubility. It is neutral in reaction, and is well adapted for hypodermatic use.

Of all the preparations of quinine at present known, the muriate of quinine and urea is the most available for subcutaneous injections. It is not official and is but little known in this country, yet it is used with the most satisfactory results in Germany (Hager's "Handbuch der pharmaceutischen Praxis"). This double salt is made by adding three parts of urea to twenty parts of hydrochlorate of quinine dissolved in fifteen parts of muriatic acid of a specific gravity of 1.061. It is soluble in its weight of water at ordinary temperatures. A fifty-per-cent. solution is used with prompt effect, followed by very slight local irritation and only a transient stinging sensation at the point of insertion.

The most important field for the hypodermatic use of quinine will probably be found in the pernicious types of malarial fevers, where the utmost promptness in securing its full effect is often requisite, and in the more common malarial derangements attended with gastric disturbances, which preclude its use by the mouth. The dose varies greatly according to the indications to be met. It may be stated as from one to twenty grains.

The official solution of the arseniate of potassium is the form in which arsenic is generally exhibited subcutaneously. It produces less local irritation if diluted with an equal quantity of water. The dose is three minims—equivalent to about gr. $\frac{1}{35}$ of arsenious acid. It may be gradually increased to a much greater amount.

Some advantages are claimed for the arseniate of sodium for hypodermatic use. The official solution may be given in the same dose as the preceding preparation.

The hypodermatic method is ordinarily not an available mode of using mercury in private practice, though the visible lesions of syphilis undoubtedly disappear under its use in this manner more rapidly than when it is given by the mouth. Nevertheless, from the force of circumstances, recourse to this means of treatment must be reserved for exceptional cases. The corrosive chloride dissolved in water is the favorite preparation of the drug. The dose, to commence with, may represent gr. $\frac{1}{40}$.

The great and persistent pain which accompanies and follows the hypodermatic administration of chloral seriously militates against its use in this manner. A fifty-per-cent. solution in water is generally employed. A more liberal dilution of a full dose, while it diminishes the local irritation, at the same time inconveniently increases the bulk of the injection. An anodyne effect is said to follow the subcutaneous use of chloral, which is not observed when it is taken by the mouth. In cholera—both epidemic and sporadic—it yields excellent results. Bartholow reports a "very formidable case, in which there seemed but little hope; sixty grains were administered hypodermatically in two hours, with the effect to stop the cramps, restore warmth, and to remove indeed all unfavorable symptoms." The same author says: "There is no means of treating cholera now known so effective as this."

Chloral may be injected in combination with morphine, or morphine and atropine. The combination constitutes a powerful anodyne hypnotic. The dose of chloral is from five to ten grains or more.

Digitaline is administered to meet the indications for which digitalis is used.

Nitroglycerin is a diffusible cardiac stimulant.

Alcoholic stimulants may be given hypodermatically in the form of brandy, whiskey, or diluted alcohol, when an immediate effect is required, and when administration otherwise cannot be accomplished. A syringeful may be injected.

Ether is extolled as a diffusible stimulant in conditions of collapse or of profound physical depression. It may be given in doses of fifteen to thirty minims undiluted.

The strength of the solutions employed for hypodermatic injections is a matter of some consequence. If too free dilution should be resorted to, the mere bulk of the injection is annoying on account of the pain consequent upon distention of the tissues or upon successive punctures of the skin, which may be necessary for its introduction. If, on the other hand, the solution should be too concentrated, it may prove very irritating. Then, again, it should be remembered that a few drops of the solution may remain in the nozzle and in the needle. This residuum will, of course, be of more importance if taken from five than from twenty drops. Two drops, for instance, will represent in the former case nearly one-half of the dose, which might be a serious loss, while in the latter it would be a waste of only one-tenth, and possibly be inappreciable so far as the effect of the drug is concerned.

As most of the remedies used hypodermatically are concentrated poisons, accuracy of dose is very necessary.

Distilled water is not essential in making the solutions; indeed, it is inferior to river, cistern, or well water, either of which will answer every requirement, if only free from visible impurities.

Strong acid and strong alkaline solutions are unfitted for hypodermatic administration. The solutions should be as nearly neutral as possible and free from irritant qualities. "Metallic salts have their irritating properties diminished or removed by being combined with albumen or with an alkaline citrate or tartrate, so as to form double salts" (Brunton).

Solutions of the alkaloids undergo subtle and unknown changes when kept for a considerable time. They develop also a fungous growth—*penicillium,*—a minute organism which multiplies at the expense of the alkaloid, and the solution deteriorates in proportion to the increase of this formation. The evaporation of the menstruum will also influence the strength of the solution. Therefore fresh solutions only should be employed, or, better still, they may be extemporaneously prepared from powders of known quantity, or from hypodermatic tablets, which are now manufactured by a number of responsible parties whose established reputations may be accepted as a guarantee of absolutely reliable products. Simple tablets, composed of a single drug or several combinations of different drugs, may be procured. They are pre-eminently adapted to the convenience of practitioners and possess many advantages over the ready-made solutions.

The use of cherry-laurel and of eucalyptus waters as menstrua for the alkaloids serves to prevent the destructive changes that render the simple aqueous solutions unstable and unreliable. The antiseptic influence of carbolic acid and of salicylic acid has been invoked for the same purpose. One to four grains of either to the ounce will not prove objectionable, and will preserve the solutions for several months. Boric acid is also employed with a like object.

The solution injected should be entirely free from solid particles. To insure this point it is well to warm the mixture before drawing it into the syringe, as heat increases the solvent action of water, and, besides, a moderately warm injection is less disagreeable to the sensations of the patient. This heat may be conveniently applied by holding the spoon containing the solution for a few moments over a gas jet, a lamp flame, or a burning match.

The prominent advantages which accrue from the hypodermatic method of exhibiting drugs consists principally in the prompt effect obtained; the opportunity which it affords to surmount the obstacles of nausea and vomiting so commonly encountered, and to overcome also any voluntary or involuntary resistance on the part of the patient, the consequence of unwillingness or inability to swallow. In many cases, too, from some idiosyncrasy of the individual, a peculiar susceptibility exists to unpleasant after-effects of certain medicinal agents when taken by the mouth. This result may, not infrequently, be moderated or obviated by the subcutaneous injection of the same remedy, and a smaller dose may be depended upon to yield given results; moreover, it is possible that a special therapeutic effect may sometimes be secured. Absorption from the subcutaneous cellular tissue is less likely to be modified by the condition of the organism than absorption from the stomach and intestines. In the alimentary canal the condition of the circulation, the presence or absence of foods, the state of the lining membrane, the nervous supply, etc., influence, regulate, and determine absorption.

With a sharp needle, of not too great size and free from rust, properly managed in a suitable locality, the pain from the operation is, as a rule, insignificant. The danger of provoking inflammation either by the puncture or by the presence of the injected liquid, of the resulting cicatrices, of conveying through the medium of the syringe specific disease, and of injecting air into a vein, are all objections that have been urged against the procedure; but with the exercise of ordinary skill, prudence, and cleanliness, the risks are so remote and so improbable that they need not be seriously considered in estimating correctly the great, palpable, and immediate advantages pertaining to this accepted and indispensable therapeutic resource. *James B. Baird.*

HYPODERMOCLYSIS.—There are few therapeutic procedures which have sprung into such well-deserved popularity as hypodermoclysis. So frequently is it employed to meet urgent surgical and medical conditions that it is difficult for us to realize that less than ten years ago it was an almost unknown method of treatment. While it had been employed sporadically, so to speak, by a number of continental investigators at various times, and very occasionally by a few American physicians and surgeons, it was not until Hildebrand, of San Francisco, published a paper upon this matter that it received the attention that it deserved. Soon after the appearance of Hildebrand's paper, the writer of this article, having become much interested not only in the employment of hypodermoclysis but in the question of the most suitable fluids for use in conditions in which hypodermoclysis was indicated, carried out a series of clinical experiments which confirmed him in his belief that we had in hypodermoclysis a ready means of supplying the body with fluid and in flushing the kidneys, thereby aiding the excretion of effete materials by these organs, and also aiding in the elimination of them through the skin.

Clinical applications of intravenous injection and hypodermoclysis side by side have, it seems, convinced the profession that for most cases hypodermoclysis is much the more useful method, and that only in very urgent cases with peculiar conditions present is it to be substituted by intravenous transfusion. In the majority of instances in which hemorrhage requires the speedy injection of normal saline fluid, it is found that the employment of hypodermoclysis is equal to the occasion and that absorption from the subcutaneous tissues takes place with sufficient rapidity to supply the blood-vessels with a proper amount of fluid. It is only when the hemorrhage is very profuse and the condition is most urgent that intravenous injection can be employed as a satisfactory measure in its place.

The conditions in which hypodermoclysis can be resorted to most satisfactorily are hemorrhages, as just mentioned; in cases of uræmia not associated with dropsy; in certain cases of pneumonia in which the infectious aspect of the case is most marked, and the action of the kidneys is imperfect; and in all of the acute infectious diseases in which it is impossible for the patient to take enough liquid by the stomach to supply his tissues and eliminating organs with a sufficient quantity of fluid. Hypodermoclysis can also be satisfactorily employed in cases of gastric ulcer, and after abdominal operations, when it is necessary to provide the body with fluid and yet in which it is impossible for fluid to be taken by the ordinary channels. Used in this way in cases of obstinate vomiting, saline infusions will very frequently relieve much suffering, allay thirst, maintain urinary flow, and in every way tend to support the patient through a trying ordeal.

Another very useful employment of saline infusions by the hypodermic method is its use in the treatment of threatened collapse in cholera infantum, in cholera morbus of a severe type, and particularly in Asiatic cholera. In the latter disease its employment has undoubtedly saved life in many instances; the saline infusion taking the place of the fluids which are purged out of the body, and diluting the toxins of the disease which are then more readily eliminated by the kidneys. Still another instance in which hypodermoclysis may be employed with great advantage is in the treatment of severe burns, not only for the purpose of overcoming shock, but, more important, for the relief of the toxæmia which seems to be the true cause of death in many cases of this character.

In regard to the employment of hypodermoclysis in the treatment of surgical shock or that which follows severe injuries, it is important to bear in mind that the condition of the patient is one in which there is a complete relaxation of the vaso-motor system. Or, in other words, he who is suffering from shock is being bled to death into his own blood-vessels. Under these circumstances the administration of fluids, either by hypodermoclysis or even by intravenous injection, is of no value so far as their bulk is concerned, unless in association with them are administered drugs which will overcome the vascular relaxation and tend to restore normal arterial tension. Many physicians ignore the well-known physiological fact that the vascular system is capable, when completely dilated, of holding many times the quantity of blood contained in the body. This fact is emphasized when we remember that at an autopsy we are wont to find practically all the blood in the body in the great veins of the thorax and abdomen. When it is recalled that not only are these great veins capable of holding all the blood which the body contains, but that the capillaries of the skin, the capillaries of the muscles, and the capillary systems of large glands, as the liver, are capable of holding immense quantities of blood when relaxed, it will readily be seen that an enormous quantity of liquid would have to be placed in the patient's body before this liquid could by its presence actually fill the widely dilated blood paths. And even if it were possible to fill the blood-vessels of the body by the profuse administration of normal salt solution, this would be of no advantage to the patient, since, under these circumstances, his heart would not be able to pump so much of a bulk of fluid and his tissues would be practically drowned. When, therefore, the use of normal salt solution by hypodermoclysis is followed by good results in the treatment of shock, it is to be clearly understood that these good results accrue not so much by the presence of an additional quantity of fluid in the blood-vessels as upon the stimulant effect which the injection may have directly or reflexly upon arterial tension and cardiac activity, and the therapeutic point is to emphasize that it is wise, under these circumstances, to employ a normal salt solution which is not absolutely indifferent, but one which really possesses some slight stimulant power over the cardio-vascular apparatus.

Another important point to be remembered in the use of hypodermoclysis is that it is not safe to infuse a greater quantity of liquid than one drachm to each pound of body weight in each fifteen minutes; as, if this amount is exceeded, the accumulation of the liquid in the system is so great that the tissues become drowned because the kidneys cannot excrete the liquid fast enough. Hypodermoclysis is also contraindicated in œdema of the lungs due to either cardiac or renal disease, in cases of chronic bronchitis with excessive secretion of mucus and fluid. In stout old persons, and in young children in particular, it must be used with great caution, if at all, and the same remark applies to parenchymatous nephritis, because the tissues are usually dropsical in this affection; and even if they are not, there is a tendency to œdema of the lungs and an imperfect eliminative action of the kidneys so that fluids rapidly accumulate in the tissues. It is hardly necessary to add that in patients having a high arterial tension hypodermoclysis is also contraindicated unless perchance uræmia or puerperal eclampsia is present, under which circumstances arterial tension should be reduced by bleeding or, in the case of puerperal eclampsia, by the administration of full doses of veratrum viride, since by this means arterial pressure is reduced and an active secretion on the part of the skin aids the kidneys in eliminating both fluid and materials from the patient's body.

Physiological experiments made by many investigators, and particularly by Dr. Sydney Ringer, of London, and Dr. Locke, of Harvard University, have proved that a most useful combination is the one which follows, and, at the suggestion of the writer, large manufacturing chemists have put this formula upon the market dissolved in one ounce (31 gm.) of sterile water in such strength that when this quantity of concentrated solution is added to a quart (litre) of pure water, it forms a normal physiological salt solution. The writer has employed this concentrated saline, after diluting it, in a great many cases with the most satisfactory results, and believes that it is the best solution for the purposes named. The formula is as follows:—℞ Calcium chloride, 0.25 gm.; potassium chloride, 0.1 gm.; sodium chloride, 9 gm.; water, 31 gm. This, when added to a quart (litre) of pure water, constitutes what is known as "normal saline solution."

The proper means of introducing normal saline solution under the skin is to employ an ordinary clean glass irrigating apparatus and rubber tube. In the distal end of the rubber tube is inserted, and if necessary tied in, a needle having a calibre about that of the ordinary antitoxin needle. The reservoir is filled with normal saline solution and hung about eighteen inches or two feet above the level at which the needle is inserted. The salt solution should be at about 110° F. in the reservoir, since it cools rapidly in its slow passage through the tube. Or, better still, it may be placed in a warm reservoir at the temperature of 100°, and the rubber tube may be coiled in a basin of water at the same temperature so that the fluid in it is maintained at the temperature of 100° during its flow. The skin where the needle is to be inserted should be thoroughly cleansed before the puncture is made, and the most satisfactory site for the injection is a little above the groin, about half-way between the navel and the anterior superior spine, or, in stout persons and in women, in the submammary region, and sometimes it may be employed on the inner side of the thighs, care being taken to avoid the great vessels. If even moderate antiseptic precautions are maintained abscess practically never results, and the operation is quite painless, although some tenderness may exist in the region of the injection for a few hours after the absorption of the fluid. The process is not a painful one at any stage. When it is wise to inject a considerable quantity of liquid into the patient at once, more than one needle and tube may be employed simultaneously. *Hobart Amory Hare.*

HYPOGLOSSAL NERVE.—(Synonyms: Nervus motorius linguæ; Nervus hypoglossus; Par nonum of Willis and the older writers; Par duodecimum; *Nerf hypoglosse* (Fr.); *Zungenfleischnerf* (Ger.).

The twelfth or hypoglossal nerve, whose name is derived from the Greek ὑπο, beneath, and γλῶσσα, the tongue, is the motor nerve of the muscles of the tongue and of those of the hyoid bone, with the exception of the digastric, stylo-hyoid, mylo-hyoid, and the superior constrictor of the pharynx. It also supplies the sterno-thyroid muscle. According to the old nomenclature it was termed the *ninth* nerve.

For the anatomy of the hypoglossal nerve consult the article on *Cranial Nerves.*

Physiology.—The hypoglossal nerve is the motor nerve for the muscles of the tongue, the sterno-thyroid muscle, and all those attached to the hyoid bone, with the exception of those mentioned above. Through its connection with the upper cervical ganglion of the sympathetic, vaso-motor fibres for the muscles of the tongue pass into it. From the gangliform plexus of the vagus and its lesser lingual branch are derived its fibres of muscular sensation. Whether any such come from the cervical nerves or through the anastomosis with the lingual is still doubtful, though Lewin says: "Recurrent fibres run from the lingualis to the hypoglossus, and these in part ascend as far as the anterior condyloid foramen, in part descend in the ramus descendens." As a rule, no influence reaches the tongue through the ansa hypoglossi, and, on the other hand, little effect is produced on the muscles supplied by the ramus descendens (the sterno-thyroid, omo-hyoid, and sterno-hyoid) by irritation of the roots of the hypoglossus.

Pathology.—Injury or disease of the hypoglossal nerve or its nucleus produces either spasm or paralysis of the muscles which it supplies.

(*a*) *Spasm of the Muscles Supplied by the Hypoglossal Nerve; Lingual Spasm.*—This is rarely idiopathic and is very infrequent as an independent affection. On the other hand, it occurs not uncommonly in certain affections of the brain, and more rarely in some of those of the spinal cord. In all forms of general convulsions, in eclampsia, epilepsy, chorea, and hysteria, we meet with it frequently, and it is often seen in company with spasms of the muscles supplied by the motor branch of the fifth nerve, and by the facial and spinal accessory nerves. At times it accompanies facial neuralgia, or is coincident with stuttering. It is not rare in bilateral athetosis, and it occurs in trismus. It may also be dependent on a definite pathological condition of the brain or its membranes, and is found in meningitis and in certain forms of cerebral and bulbar paralysis. It sometimes occurs in certain diseases of the spinal cord, as progressive muscular atrophy, in which the disease probably extends upward and involves the hypoglossal nucleus.

In many of these cases we may suppose some injury of the nucleus, or, possibly, of the nerve itself, but we must not forget that lingual spasm may in all probability be produced by lesion of the cortical motor centre of the tongue at the base of the ascending frontal convolution, or possibly of some of the fibres which connect this with the hypoglossal nucleus. The spasm is also at times apparently due to peripheral or reflex causes, as in some cases in which it occurs with tic douloureux or in company with the spasms of neighboring muscles. In one case it was apparently caused by caries of the teeth, which had produced an ulceration of the gums.

The spasms vary in character in different cases. They may be either tonic or clonic. They may consist in mere protrusion of the tongue. Sometimes the tongue is thrust violently forward against the teeth, or it may be protruded and rapidly retracted, as in Berger's case, in which this occurred as often as fifty or sixty times a minute. Sometimes the tongue seems to be simply rolled round in the mouth. Again, the movements may be very varied and irregular. These spasms may also affect the sterno-thyroid, sterno-hyoid, and thyro-hyoid muscles. There is usually no pain or swelling, but the spasms may be preceded by a sensation of numbness in the tongue, or discomfort and oppression about the throat above the larynx. The tongue sometimes feels too big for the mouth. The spasms are for the most part independent of the acts of speaking, masticating, and swallowing, neither affecting them, unless when at their height, nor being affected by them. In certain cases, however, the spasms are induced or greatly aggravated by such acts.

The tonic spasms likewise may either occur independently, or they may be induced by voluntary efforts to move the tongue. Those of the latter class have been divided into articulatory and masticatory spasms, according as they were produced more especially by attempts to move the tongue in speech or in eating. These articulatory spasms are known as articulatory hypoglossal cramp or aphthongia (aphthongie, Fleury), from the Greek, *a* privative, and φθογγός, the voice. In some cases the tongue is glued to the hard palate whenever the patient attempts to speak; in others (masticatory cramp) the food is ejected from the mouth by the involuntary action of the tongue during mastication. In Ganghofner's case, in which there was spasmodic contraction of the tongue in ordinary speech, singing, rapid speech, and the declamation of previously known pieces were more easily accomplished.

The *prognosis* of independent lingual spasm is generally good, though the disease may be obstinate and persistent.

Treatment. There is no symptomatic treatment, as such, for lingual spasm except the application of electricity. The constant current may be applied directly to the tongue or to the hypoglossal nerve in the neck. The faradic may also be used in the same manner. These are the most useful means of direct treatment. When the spasm occurs as a symptom, or in the course of some other disease, the primary disease is, of course, to be treated. In independent spasm our first care should be to remove, as far as possible, all predisposing or exciting causes. The teeth and gums should be carefully examined, and any source of reflex irritation should be allayed. Means should also be taken to improve the general health, and to strengthen the resisting powers of the nervous system. Thus fresh air, good wholesome diet, change of scene, and general tonics and sedatives—quinine, iron, and bromide of potassium or sodium—should be our principal aids.

(*b*) *Paralysis of the Muscles of the Tongue ; Glossoplegia.*—Section of the hypoglossus in dogs, when bilateral, causes total paralysis of the tongue. The animals cannot drink, and are apt to bite the tongue, which hangs loosely out of the mouth (Landois).

In man paralysis of the muscles of the tongue is usually central. It may be produced by lesions of the cortical motor centre of the tongue, or of the fibres which connect it with the hypoglossal nucleus, or by lesions of the nucleus itself or of the hypoglossal nerve. Hence it is found in cases of cerebral or bulbar hemorrhage or softening, and in certain other forms of cerebral disease, in progressive bulbar paralysis, and in those forms of spinal disease in which the ganglion cells of the hypoglossal nuclei are affected. Thus it is sometimes seen in the advanced stage of tabes dorsalis and in descending secondary sclerosis. The hypoglossal nerve itself may be affected either intracranially, as by the pressure of tumors at the base of the brain, or extracranially, either at its exit from the cranium or in the neck. This may be done by injuries of the upper cervical vertebræ, such as fracture of the atlas, or by tumors or wounds of the neck, by aneurism of the vertebral artery, or by carious or syphilitic processes.

Symptoms. Hypoglossal paralysis may be either unilateral or bilateral, according as one or both nerves are involved, though bilateral paralysis *may* be caused by a unilateral *cortical* lesion. In unilateral paralysis the tongue, when protruded, deviates to the affected side. This is due to the unbalanced action of the healthy genioglossus muscle, which in contracting not only throws the tip of the tongue forward, but directs it at the same time to the opposite side. In bilateral paralysis the tongue cannot be protruded, but lies perfectly motionless in the mouth. It is relaxed, anæmic, often atrophied, and deeply furrowed. Not infrequently there are fibrillary twitchings. In unilateral paralysis these symptoms may appear on the affected side of the tongue. "When the tongue is paralyzed it falls backward in the cavity of the mouth as the patient lies on his back, and the glottis becomes partially or wholly closed by it. Paralysis of the tongue thus contributes to the production of stertorous breathing in cases of apoplexy, and may even cause asphyxia, when the paralysis is bilateral and more or less complete." Thus closure of the glottis may be produced in deep narcosis.

In lingual paralysis the speech is much affected, and the power of articulation greatly impaired. In bilateral paralysis, with atrophy, the speech is said to be completely inarticulate and unintelligible, and even when the paralysis is slight, the singing of high notes and falsetto is impaired. Ross states that difficulty is first experienced in pronouncing the letters, s, sh, l, e, i, and at a later period k, g, r, etc.

Mastication is interfered with also to a certain extent, as the tongue cannot direct the food nor compress it against the teeth. Deglutition is likewise affected by the falling backward of the tongue, and also because the food cannot be properly collected on its dorsum and pushed back into the pharynx. Hence regurgitation into the mouth occurs. The salivation of the affected side, which is a prominent symptom in certain cases of lingual paralysis, has not yet been shown to be due to anything more than reflex action. The slight diminution in the tactile sensibility of the affected side, sometimes noticed, seems in certain cases not to exist.

Diagnosis. This is usually very easy. Hutchinson's method of testing the condition of the lingualis muscle is very simple. He holds it between his thumb and finger and bids the patient protrude the tongue. If either side be paralyzed, the muscle of that side will be flaccid and relaxed, and will not harden like the healthy one on contraction.

The *prognosis* is naturally dependent on the cause.

Treatment. This must, of course, be directed against the primary cause. Locally, the galvanic or faradic current may be applied either to the tongue itself or to the nerve in the neck. *William N. Bullard.*

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HYPOPHOSPHITES.—I. GENERAL MEDICINAL PROPERTIES OF THE HYPOPHOSPHITES.—Physiologically, salts of hypophosphorous acid are simply bland saline representatives of their respective bases, and produce no special effect whatsoever, due to the hypophosphorous acid of their composition. What place they hold in medicine has been from theoretical considerations purely. The idea has been that because these salts contain phosphorus in a comparatively low state of oxidation, they will affect the system after the manner of phosphorus itself, and, especially, will yield phosphorus in such chemical combination as to be assimilable for the nutrition of nerve tissues. Clinical experience, however, has failed on the one hand to get the expected results, while on the other it has shown that nearly all of a dose of a hypophosphite, swallowed, reappears in the urine unchanged. Those who prescribe these salts, do so in cases of neuralgia and of nerve exhaustion or malnutrition generally, and in phthisis.

With the exception of the potassium salt the hypophosphites are harmless, and they are, with manufacturing pharmaceutists, favorite ingredients of emulsions of cod-liver oil.

II. THE HYPOPHOSPHITES USED IN MEDICINE.—The hypophosphites official in the United States Pharmacopœia are the iron, potassium, sodium, and calcium salts. Ferric hypophosphite will be found treated of under *Iron.*

Potassium Hypophosphite, KH_2PO_2. The salt is official in the United States Pharmacopœia as *Potassii Hypophosphis,* Potassium Hypophosphite. It occurs in "white, opaque, hexagonal plates, or crystalline masses, or a granular powder, odorless, and having a pungent, saline taste; very deliquescent. Soluble at 15° C. (59° F.) in 0.6 part of water, and in 7.3 parts of alcohol; in 0.3 part of boiling water, and in 3.6 parts of boiling alcohol; insoluble in ether" (U. S. P.). If triturated or heated with an oxidizing agent, such as a nitrate, the mixture will explode. Because of deliquescence, the salt must be kept in well-stoppered bottles.

Potassium hypophosphite follows the rule of potassic salts of being irritant in large concentrated dosage, but in therapeutic doses it is locally bland enough. Again, because a potassic salt, it may tend to induce retrograde metamorphosis of lowly organized material, and hence lead to softening of cheesy deposits in the lungs. This particular hypophosphite is therefore, theoretically at least, not without a possible dangerous tendency in phthisis. The salt is administered in solution, aqueous or syrupy, in doses of from 0.65 to 2 gm. (gr. x.–xxx.) three times a day. A convenient form of giving it is in the official *syrup of hypophosphites* (see *postea*).

Sodium Hypophosphite, $NaH_2PO_2H_2O$. The salt is official in the United States Pharmacopœia as *Sodii Hypophosphis,* Sodium Hypophosphite. It occurs in "small, colorless, transparent, rectangular plates of a pearly lustre, or a white granular powder, odorless, and having a bitterish sweet, saline taste. Very deliquescent on exposure to moist air. Soluble at 15° C. (59° F.) in 1 part of water, and in 30 parts of alcohol; in 0.12 part of boiling water, and in 1 part of boiling alcohol; slightly soluble in absolute alcohol, insoluble in ether" (U. S. P.). Like the potassium salt, this also will explode on trituration and with an oxidizing agent, and must be kept in well-stoppered bottles.

This sodic salt is a generally serviceable and permissible hypophosphite, having, as usual with compounds of sodium, no active individuality due to the basic radical. It may be given in the same manner and dosage as the potassic salt.

Calcium Hypophosphite, $CaH_4(PO_2)_2$. The salt is official in the United States Pharmacopœia as *Calcii Hypophosphis,* Calcium Hypophosphite. It occurs as "colorless, transparent, monoclinic prisms, or small, lustrous scales, or a white, crystalline powder, odorless, having a nauseous, bitter taste, and permanent in the air. Soluble at 15° C. (59° F.) in 6.8 parts of water, and in 6 parts of boiling water; insoluble in alcohol" (U. S. P.).

Being a salt of lime, which salt is assumed to have a reconstituent tendency in phthisical conditions, this hypophosphite is theoretically the one to be preferred for administration in consumption. It is also the one best borne when the stomach or bowels are irritable, as so often happens in the disease mentioned. The salt is given in the same manner and dose as the potassic salt.

The following pharmaceutical preparations of the hypophosphites are official in the United States Pharmacopœia; *Syrupus Hypophosphitum,* Syrup of Hypophosphites. This is an aqueous solution of potassic, sodic, and calcic hypophosphites (wherein the latter salt has been made fully to dissolve by the addition of a little hypophosphorous acid), made into a syrup by the addition of sugar, and flavored with spirit of lemon. By weight the preparation contains fifty per cent. of sugar, and, of the hypophosphites, 4.5 per cent. of the calcic salt, and 1.5 per cent. each of the potassic and sodic. By measure 4 c.c. (fl. ʒ i.) contains about 0.18 gm. (gr. iij.) of the calcic hypophosphite, and 0.06 gm. (gr. i.) each of the potassic and sodic salts. This syrup forms a convenient preparation for prescription, and may be ordered in doses of from one to two or three teaspoonfuls, several times a day. *Syrupus Hypophosphitum cum Ferro,* Syrup of Hypophosphites with Iron. This preparation is simply the foregoing syrup charged with one per cent. each of lactate of iron and potassium citrate—this particular iron salt being selected for pharmaceutical reasons only. This syrup forms a convenient combination of hypophosphites with a chalybeate, and may be given, where such combination is indicated, in doses the same as those of the simple syrup. *Edward Curtis.*

HYSSOP.—See *Labiatæ.*

HYSSOP, HEDGE.—See *Scrophulariaceæ.*

HYSTERECTOMY (from ὑστέρα, the womb, ἐκ out, and τέμνειν, to cut) is the removal of the uterus by a cutting operation and may be accomplished through an incision in the abdominal wall (cœlio-hysterectomy), by way of the vagina (kolpo-hysterectomy), or by a combination of both methods.

Cœlio-hysterectomy includes (*a*) supravaginal amputation and (*b*) the complete removal. Kolpo-hysterectomy at the present time practically always means the complete removal of the organ.

While dim records of the operation are found as early as 100 A.D., when Soranos[1] is said to have removed the uterus per vaginam, yet as late as 1882, when Ahlfeld[2] collected the records of sixty-six cases in which the uterus had been removed through the abdomen with only thirteen recoveries, the recorded cases were very few and the mortality was frightful, ranging from eighty to ninety per cent. In its present form, and with its very low mortality of from three to five per cent. when done for the same indications, the operation is essentially a modern one, and as such has been developed during the last fifteen years, and largely in America by Baer, Goffe, and Kelly. With the improved technique and lessened mortality the range of *indications* for its performance has widened, until now it may include:

For the Abdominal Operation.—All solid or cystic tumors of the uterus; cancer; uterine rupture during labor; certain conditions of puerperal sepsis; pregnancy complicated by pelvic deformity, cancer, or other serious obstacle to the passage of the child; uterine prolapse or inversion; and incidentally as a step in the removal of complicated suppurative conditions of the uterine appendages.

For the Vaginal Operation.—Bilateral suppurative conditions of the appendages; prolapse; cancer; pregnancy with cancer before the sixth month; certain septic conditions of the uterus; certain rare conditions which may require the ablation of a small movable uterus.

For the Combined Operation.—Cancer; certain complicated fibroids; failure to secure hæmostasis from below.

For the details of these indications the reader is referred to the articles treating of the various conditions mentioned.

The operation of hysterectomy is always formidable, and as conditions may arise at any time which tax the resources and nerve of the most skilled, and where hesitation or lack of expedient may mean the immediate death of the patient, it should not be undertaken without an adequate practical knowledge both of aseptic surgical technique as applied to abdominal surgery and of the anatomy of the pelvic contents, particularly of the relations of the bladder, ureters, rectum, uterine and ovarian arteries, and large venous trunks.

TECHNIQUE OF CŒLIO-HYSTERECTOMY.—The patient is prepared as for any abdominal operation; the intestines are thoroughly emptied; for several days she is encouraged to drink water freely; the skin of the abdomen is carefully disinfected; the vulva and vagina are cleansed and packed with 1 to 4,000 bichloride gauze for two days, and the limbs covered with cotton and a bandage to prevent chilling of the surface.

The instruments needed are: Two scalpels, two pairs of strong blunt-pointed scissors, two anatomical forceps, six traction forceps, twelve short hæmostatic forceps, eight long clamp forceps, pedicle needle, retractors, long and small curved needles, strong silk or kangaroo tendon, slightly chromicized catgut nos. 1, 2, 3.

The patient is put in the Trendelenburg position. The abdomen is opened by a median incision beginning half an inch above the pubes and extending upward, as far as may be necessary to allow the delivery of the tumor. In making this incision care must be taken not to injure the bladder which sometimes is drawn high up. Remembering that any injury to the capsule of fibroids will cause free and troublesome bleeding, adhesions are carefully detached, slight ones being wiped free by a bit of gauze and firmer ones divided between two ligatures. Dense adhesions to intestine may require that small areas be detached from the surface of the tumor. The tumor being freed from adhesions is lifted up and out off the abdominal cavity. Large flat gauze pads with strings attached are wrung out of hot sterile salt solution and placed so as to protect and cover the intestines. The finger is passed under the broad ligament on the more accessible side, and, guided by it, the pedicle needle, threaded with a long, strong ligature, is passed through a portion free from veins, so as to include the ovarian artery. This ligature is then firmly tied and occludes the artery and the adjacent large venous trunks. The ovary is to be left outside the ligature, unless it is so diseased that its removal is desirable. A second bite with the same ligature ties off the round ligament. A long clamp is now placed so as to control the vessels on the uterine side and the tissues between clamp and ligatures are divided with the scissors. If the ovarian artery on the other side is easily accessible, it is tied in the same way. Careful inspection of the anterior surface of the uterus will now determine the upper limit of the bladder, and a transverse incision through peritoneum only is made a third of an inch above this point, running from the lower edge of the cut in the broad ligament across the uterus to a corresponding point on the other side. The bladder is freed from the uterus by being carefuly wiped down with a piece of gauze held by fingers or forceps. The uterine artery is now exposed, and a finger passed down by the side of the cervix can feel its pulsation. This artery is to be carefully ligated on one side and then on the other, *close* to the side of the cervix, the pedicle needle being passed forward and not outward, so as to avoid the ureter. The cervix is then divided and the uterus and tumor are removed.

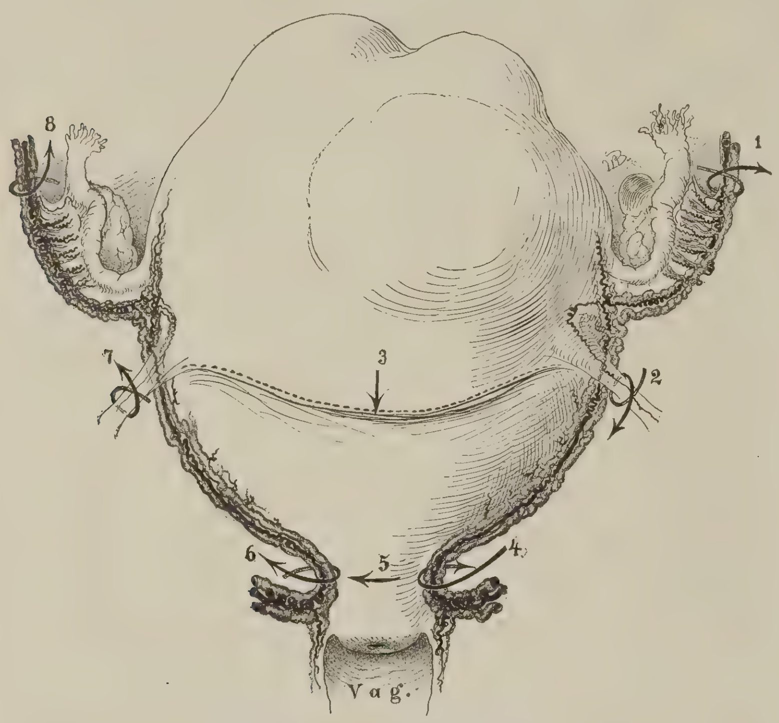

FIG. 2775.—Showing Diagrammatically the Blood Supply to the Uterus and the Successive Steps in Kelly's Method of Supravaginal Hysterectomy.

When the operator has attained confidence in his technique, the procedure is greatly simplified especially in difficult cases, by first securing the ovarian and round ligament arteries on the more easily accessible side, freeing the bladder, securing the uterine vessels, cutting freely across the cervix until its tissue is nearly divided, catching the lower portion of the cervix with traction forceps so as to have it under control in case of unexpected hemorrhage. Tearing carefully the last fibres of the cervix, the operator will see the remaining uterine artery arching across the torn space. After this has been clamped or ligated, and the remainder of the broad ligament has also been clamped, the tumor is removed (Fig. 2775). All bleeding points having been secured by ligatures the edges of the cervical stump are carefully approximated with catgut, and the anterior and posterior peritoneal edges of the pelvic wound brought together, so as to cover in all raw surfaces and leave finally only a seam across the pelvis. The abdomen is then closed.

When it is considered best to remove the entire cervix after securing the arteries by ligature or clamp, the uterus or the cervical stump is drawn away from the vagina and the dissection is carried down by scissors, keeping close to the cervix so as even to leave a slight ring of its tissue in place. When the cervico-vaginal junction is reached the scissors are pushed through into the vagina and with this opening as a guide the remaining tissues are easily divided. All bleeding points having been secured, a piece of sterile gauze is pushed down into the vagina so that the upper part comes just above the cut vaginal edges, and the peritoneal edges are drawn together and sewed so as to close off the peritoneal cavity as in the supravaginal operation. The gauze drain is left in place five or six days.

In certain instances, especially when there are inflammatory disease of the appendages and extensive adhesions so that the tumor masses are fixed in the pelvis and the vessels covered in out of reach, it becomes necessary to incise the uterus anteriorly, always keeping strictly in the middle line, and rapidly to enucleate the tumor or tumors. The uterus then being collapsed and its relations easily recognized, the vessels can be secured and the operation completed.

Very large subperitoneal tumors under the vesical peritoneum, or in the broad ligament, are often best removed by a bisection of the tumor, as this allows the tumor to roll up and out on to the surface with the least handling and injury to its cellular investment.

Howard Kelly,[3] in a case of fibroid reaching the umbilicus and with extreme adhesions to the colon and

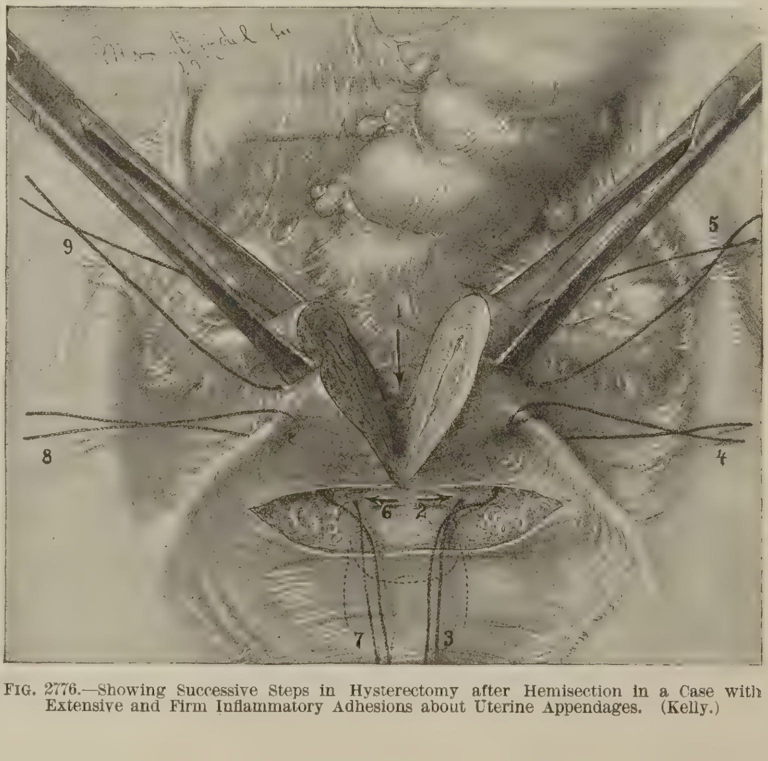

FIG. 2776.—Showing Successive Steps in Hysterectomy after Hemisection in a Case with Extensive and Firm Inflammatory Adhesions about Uterine Appendages. (Kelly.)

adjacent structures, first dissected the bladder from the cervix, then cut cautiously through the cervix transversely, tearing the last few fibres on each side, and as the uterine vessels came into reach clamped them with short-jawed forceps, compressed the vessels and cervix above the incision with long-jawed forceps, cut the vessels, and as the tissues could be pulled into reach after the cervix was loosened, secured the vessels up to the upper edge of the broad ligament, dealing with the adhesions to the colon after the mass had been entirely freed from below and lifted out of the abdomen.

Where there is double pyosalpinx with dense adhesions covering the uterine appendages and all contiguous structures, very great advantages are secured by a preliminary bisection of the uterus as described by Faure,[4] of Paris, and Howard Kelly,[5] of Baltimore. Kelly proceeds as follows: If the uterus is buried out of view, the bladder is first separated from the rectum and the fundus found; large abscesses, cysts, or hæmatomata are evacuated by puncture or aspiration; the abdominal cavity is carefully packed off from the pelvis. The uterine cornua are each seized by traction forceps and lifted up; the uterus is incised antero-posteriorly in the middle line, while its cornua are pulled up and drawn apart (Fig. 2776). With a third pair of forceps the uterus is grasped at one side on its cut surface as far down in the angle as possible, including both anterior and posterior walls. The traction forceps of the same side is then released and used for grasping the corresponding point on the opposite cut surface. In this way two forceps are constantly in use at the lower point. The bladder being pushed down or away from the uterine surface, the bisection is carried down to the cervix, or, if the operator prefers, into the vagina. The uterine canal must be followed in the bisection, using a director, if necessary, to keep it in view. Forceps now grasp the uterus well down in the cervical portion, if it is to be a supravaginal amputation, and the cervix is bisected on one side. As soon as it is divided and the uterine and vaginal ends begin to pull apart, the under surface of the uterine end is caught with a pair of forceps and pulled up, and the uterine vessels, which can now be seen, are clamped or tied. As the uterus is pulled farther up the round ligament is exposed and clamped, then a clamp is applied between the cornu and the tubo-ovarian mass and the half uterus removed. The same is done on the other side, and there are left only the tubo-ovarian masses for enucleation under the best possible conditions. Often the tube and ovary can just as well be taken out with the corresponding half of the uterus, leaving the separate enucleation for the most difficult cases. The most critical point in the operation is the bisection of the cervix and the securing of the uterine vessels. The cervix must be slowly and cautiously severed with steady, careful traction on the uterus, so as to prevent sudden tearing out and rupture of the vessels with frightful hemorrhage. By cutting so as to leave a tongue on each side of the cervix the vessels can be caught at a higher level and farther from the ureters.

Kelly also states that if the uterus is densely adherent to the rectum all the way up to the fundus the anterior portion of the uterus should be bisected, the cervix divided, the uterine vessels caught, and the rest of the uterus carefully divided up its posterior surface in a direction from the cervix toward the fundus, leaving a thin layer of uterine tissue on the gut at any point where it may seem necessary.

When the uterus is retroflexed with the fundus low in the pelvis and the cervical end thrust up near the symphysis, it may be caught at any convenient point on its anterior surface and drawn up toward the incision. The vesical fold of peritoneum is cut across and pushed down, and the cervix exposed and caught with two traction forceps, one above and one below. As the cervix is drawn up it is cautiously divided across its axis so as to sever the vaginal from the corporeal portion. As the ends are pulled apart the uterine vessels are exposed and clamped. The uterus may then be bisected from below upward or removed *en masse.*

Cœlio-hysterectomy for Cancer.—Cullen[6] states that this operation should be preferred in all cases when the patient is not too stout, but that to employ it in very fat individuals is unsatisfactory, both on account of the large quantity of adipose tissue in the abdominal wall, which materially increases the distance to the pelvic floor, and on account of the deposition of fat between the folds of the broad ligament and beneath the peritoneum of the pelvic floor, which renders the free dissection of the ureters and uterine arteries exceedingly difficult.

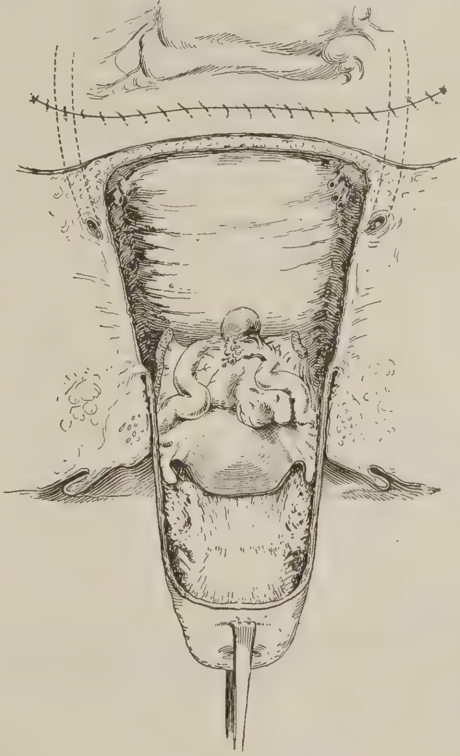

FIG. 2777.—Werder's Operation. The uterine attachments have been separated from above and the uterus pulled down through the vagina by a traction forceps attached to the cervix. The vesical and rectal peritoneum has been united by a running suture. The operation is completed by dividing the vagina at its reflection an inch within the vulva.

The great advances in the technique of hysterectomy for cancer have been made by Ries,[7] Clark,[8] Rumpf,[9] and Werder.[10] Ries, in 1895, published a method involving the removal of the pelvic lymph glands after slitting the peritoneum back to the posterior pelvic wall as far as to the point at which the common iliac artery divides, Rumpf being the first to carry out this procedure on the living subject. Clark in 1895, having made the ureters prominent by the insertion of bougies, carried the operation to the point where the uterine artery is exposed, then spread the layers of the broad ligament apart, dissected the uterine artery out for a distance of 2.5 cm. from the uterus to beyond the vaginal branch and tied it, removing the broad ligament close to the iliac vessels and carrying his dissection well down on the vagina even if the disease did not apparently extend beyond the cervix. With all these methods there is the grave disadvantage that the carcinoma is very apt to come in contact with peritoneal or raw surfaces, so that there is always the risk of septic infection or of implanting carcinoma cells in healthy tissue. In 1898 Werder, to avoid this, devised a method by which, after the careful separation of the structures from above, the *uterus and vagina* are removed *en masse* from below (Fig. 2777).

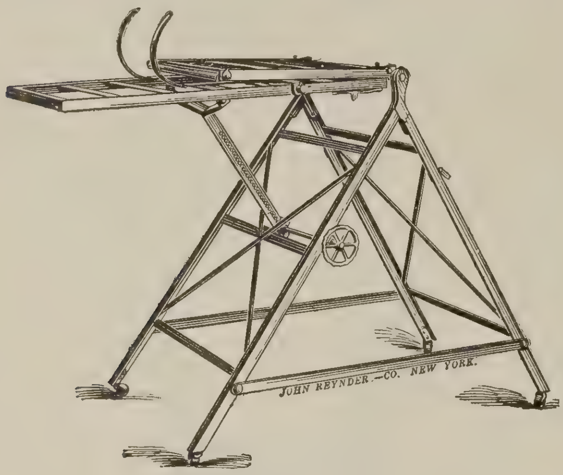

Fig. 2778.—Pryor's Table Arranged for Vaginal Hysterectomy in the Lithotomy Position.

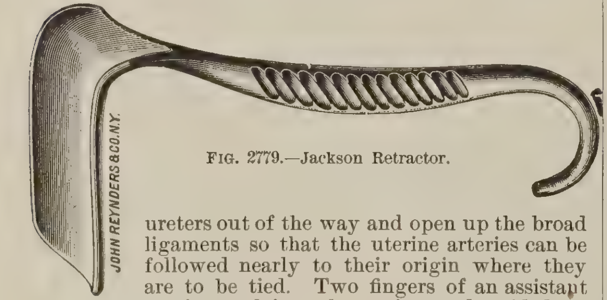

Fig. 2779.—Jackson Retractor.

The plan of the operation now is: To scrape away the broken-down carcinoma tissue, preferably several days before the operation, the bleeding surface being seared over with the thermo-cautery. If desired, bougies can be passed into the ureters. The patient is then placed in the Trendelenburg position, the abdomen is opened, the ovarian arteries are secured, and the bladder is separated not only from the front of the uterus but from the broad ligament on either side as widely as possible, so as to get the ureters out of the way and open up the broad ligaments so that the uterine arteries can be followed nearly to their origin where they are to be tied. Two fingers of an assistant are inserted into the vagina, and guided by them the dissection is carried down in front between bladder and vagina to within an inch of the vulva. The uterosacral ligaments are divided with scissors, and the rectum is separated from the vagina to the same level. The lateral walls of the vagina are then freed, and lastly the bases of the broad ligaments are divided. This step is generally conceded to be the most difficult in the operation. The uterus and vagina, being now completely freed, are pushed down into the pelvic outlet, an assistant making strong traction on the cervix from below. The removal of the pelvic glands after slitting the peritoneum of the posterior pelvic wall to the point where the common iliac artery divides, and the stitching of the anterior and posterior peritoneal flaps so as to close off all raw surfaces from the peritoneal cavity, complete the abdominal part of the operation, and the abdominal incision is then closed. The patient is now placed in the lithotomy position and, guided by a finger in the rectum and a sound in the bladder, the surgeon amputates the inverted vagina with the knife or with a thermocautery and places a light gauze dressing in the space left in the vaginal vault.

Technique of Kolpo-hysterectomy.—The patient is prepared in every way as for the abdominal operation, so that in case of failure to secure hæmostasis, or of other complication, there need be no delay in opening the abdomen. A final scrubbing of the vulva and vagina is made with a one-per-cent. lysol solution by means of a long soft brush or piece of sterile gauze wound around the ends of two fingers. While the operation may be done on any ordinary table, it is very desirable to be able at any time to tilt the patient into the Trendelenburg position so as to free the pelvis from abdominal viscera. This is easily accomplished with the table shown in Fig. 2778, which is strong, portable, and useful for any gynæcological work.

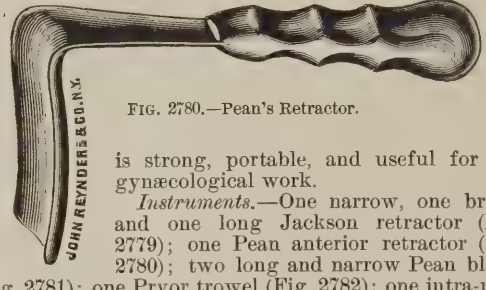

Fig. 2780.—Pean's Retractor.

Instruments.—One narrow, one broad, and one long Jackson retractor (Fig. 2779); one Pean anterior retractor (Fig. 2780); two long and narrow Pean blades (Fig. 2781); one Pryor trowel (Fig. 2782); one intra-uterine traction forceps; two strong bullet forceps; four traction forceps (Fig. 2783); Pryor's retracting director (Fig. 2784); two strong scalpels with good bellies; long, strong, sharp and blunt-pointed scissors, curved on the flat; eight pairs of Pryor's hysterectomy forceps (Fig. 2785); and other material as under *cœlio-hysterectomy.*

The most frequent and imperative indication for removal of the uterus per vaginam is the presence of bilateral suppurative disease of the appendages, and the clamp operation for this condition will be described first.

The steps of the operation are: The curetting of the uterine cavity; the opening of the posterior cul-de-sac; the incision in front of the cervix and separation of the bladder from the uterus; the hemisection of the uterus; the freeing of the appendages; the bringing down of first one and then the other half and its appendages, clamping its arteries and removing it; the dressing.

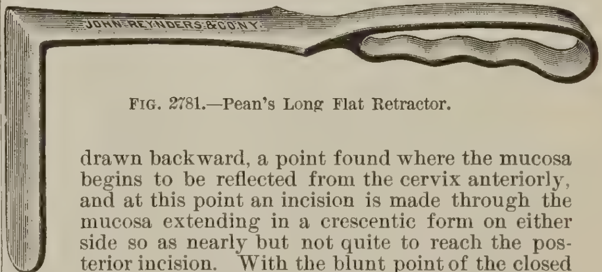

Fig. 2781.—Pean's Long Flat Retractor.

The patient is put in the lithotomy position with the coccyx well over the edge of the table. The uterus is curetted and irrigated; the instruments used are discarded and the hands washed. A posterior retractor is introduced, the cervix exposed and drawn forward with a pair of traction forceps or, better, with Pryor's intra-uterine traction forceps, and a transverse incision the width of the cervix made with knife or scissors at the point where the vaginal mucosa is reflected posteriorly from the cervix. This incision is kept close to the posterior surface of the uterus until the peritoneal cavity is opened, which is usually accomplished without much difficulty. The index fingers are then passed in and the opening is sufficiently enlarged by tearing. An exploring finger is passed through this opening and the condition of the appendages learned. A gauze pad with string attached is passed up to protect the intestines. The cervix is then drawn backward, a point found where the mucosa begins to be reflected from the cervix anteriorly, and at this point an incision is made through the mucosa extending in a crescentic form on either side so as nearly but not quite to reach the posterior incision. With the blunt point of the closed scissors directed toward the cervix and used as one would a periosteal elevator the tissues are pushed up along the anterior surface of the uterus, aided after a little by the finger. This is done carefully and gently so as not to injure the bladder, and over a width of about two fingers, the fact being kept in mind that at the side it is easy to tear into the arteries or lateral venous trunks. When some little separation has been obtained, a long anterior retractor, or trowel, is inserted beneath the bladder so as to lift it up out of the way, any restraining fibres being snipped with scissors. The finger can sometimes be pushed up to the reflection of peritoneum from bladder to uterus and on through the tissues into the peritoneal cavity, or the peritoneum at this point may be opened with scissors. At other times it is not easy to reach as high as this.

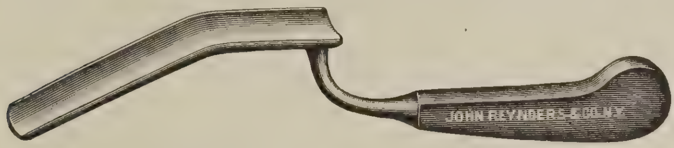

FIG. 2782.—Pryor's Trowel Anterior Retractor.

The tissues having been separated anteriorly and posteriorly, the fundus can sometimes, when small and movable, be turned forward and brought through the anterior incision by taking higher and higher grasps with traction forceps, so that clamps or ligatures can be applied to the vessels of one side and after division with scissors between clamp and uterus the other side easily secured, but usually it is better first to divide the uterus in the middle line. This is accomplished by grasping the anterior lip of the cervix on either side with traction forceps, cutting upward through the anterior uterine wall in the middle line as far as convenient, taking a fresh grasp higher up on either side, cutting again, and repeating this until the fundus is reached. Then the broad-curved director is passed behind the cervix close along the posterior wall of the uterus, care being taken by a finger passed over the fundus that no folds of intestine are between it and the uterine body, and an assistant pressing the handle firmly backward against the perineum while the bladder is held up out of the way by the trowel; the end of the director then appears above the fundus. With a strong bistoury the groove in the director is entered from above and the uterus split in the middle line. One half, usually that on the patient's right, is then dragged down with traction forceps while the other is pushed up by four fingers of the operator's right hand. These fingers, having been passed behind the dragged-down side, free the appendages by pushing and working from below upward and bring them out into the vagina. The half uterus and appendages being free, a long clamp forceps is passed from below upward over the broad ligament so as to clamp the uterine artery, and a second forceps from above downward to occlude the ovarian. The tips of the forceps should overlap a trifle but should be laterally a third or half inch apart so as not to tear the tissues when the upper forceps is turned down parallel with the lower. The half uterus and its appendages are then cut away, and finally the remaining side is freed, brought down, clamped, and cut away in the same manner.

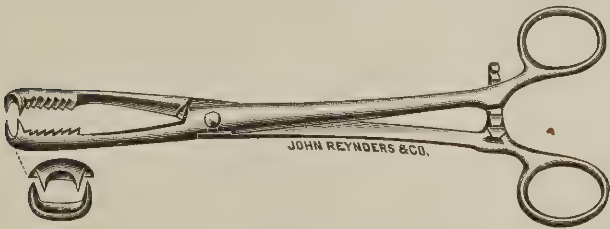

FIG. 2783.—French Traction Forceps.

It is to be noted that the first attempt at hæmostasis is made after the uterus has been divided and the appendages have been freed and brought down into the vagina. Occasionally a posterior vaginal artery will need immediate control, but usually the hemorrhage is not serious. If preferred, stout silk ligatures may be used in place of the clamp forceps, while some surgeons favor the angiotribe or Skene's electric clamp.

During the whole operation as few instruments as possible are to be in the vagina. Any premature attempt to use the clamps adds greatly to the difficulties. In applying the forceps to the uterine artery the cervix is to be drawn sharply to the opposite side so as to straighten the artery and increase the distance between the cervix and the point where the artery is in relation with the ureter.

Gauze pads secured by strings are now introduced above the forceps, the perineum is retracted, and the bladder held up by a trowel. The head of the table is lowered and a careful inspection made of the stumps and pelvic contents. Any bleeding points are secured. The gauze pads are removed and the pelvis, especially the cul-de-sac, is carefully cleansed. A piece of iodoform gauze is inserted between the forceps and the vaginal wall on each side. Each set of forceps is then drawn toward the lateral pelvic wall by means of a long, narrow, flat retractor. Between them enough strips of folded gauze are inserted snugly to fill the space. These strips extend above the forceps and down to the vulva. As each strip is inserted it is pressed to one side by one of the long retractors, and this is done until the whole cavity is firmly packed from side to side. A self-retaining catheter is introduced; the sphincter ani is dilated, and the patient lowered to a horizontal position. As a final step, a piece of plain gauze is wrapped about the projecting ends of the forceps and tied. Pryor[11] considers this careful packing of the vagina a very essential portion of the operation, both as a means of securing efficient drainage and in preventing the retraction of the upper portion of the stump after the forceps has been removed.

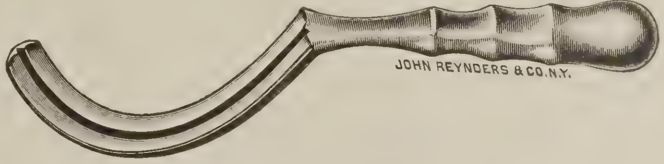

FIG. 2784.—Pryor's Retracting Director.

In cases in which the uterus is small and movable or in which the presence of cancer of the fundus or sepsis makes the hemisection inadvisable, the procedure may be as follows: After it has been curetted, the cervix is to be closed by three or four stout silk sutures, the ends of which are left long, so as to be used as tractors. An incision is then made through the vaginal mucous membrane

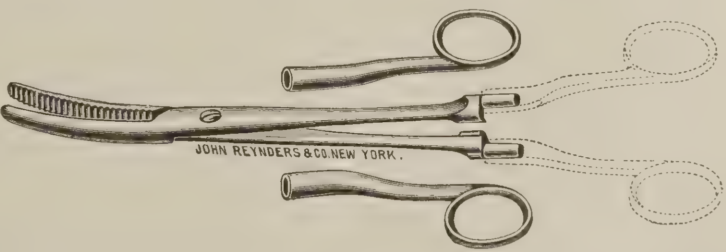

FIG. 2785.—Pryor's Hysterectomy Forceps with Removable Handles.

entirely around the cervix and extending into the posterior cul-de-sac. Then, in order to secure the greatest amount of space, a longitudinal median incision is made for an inch or more toward the base of the bladder, and the bladder stripped away from vaginal wall and uterus. Gauze sponges with strings are now pushed up to protect the intestines and the appendages are freed by two fingers working upward through the posterior cul-de-sac. The uterus is then held only by the tissues of the broad ligaments. The cervix is drawn firmly down and toward the left, and the lateral vaginal wall held out of the way by a retractor. The left index finger is placed beneath the right broad ligament, and a stout silk ligature is passed about 1 cm. up and away from the cervix and securely tied. The included tissue is cut near the cervix with stout scissors and a second and third bite are taken and the tissues divided. The uterine arteries having been secured and divided, one may often, by pushing the cervix back, bring the fundus and appendages down into the vagina and then ligate the remainder of the right broad ligament from above. After one side has been freed the uterus comes down lower or out of the vagina and the remaining broad ligament may then be more easily tied off and the uterus removed. The field of operation is now sponged clean. Each ligature is examined and any that seems at all loose is at once replaced. Especial care is to be given those placed around the upper portion of the broad ligament. All bleeding points having been secured, the gauze sponges are removed, the anterior and posterior peritoneal folds are brought together by one or two points of suture, the ligature ends are gathered together in two bunches and cut just inside the vagina, and the cavity is packed moderately firmly with gauze. If clamps are used the packing is to be as already described. When the fundus cannot be inverted into the vagina the ligating and cutting may have to be done alternately on either side until a ligature can be passed over the top of the broad ligament.

Kolpo-cœlio-hysterectomy, or combined hysterectomy, is accomplished by freeing the cervix from below and finishing the remaining steps of the operation from above. It is most strongly indicated in cases of cancer of the cervix when the body of the uterus is considerably enlarged, as by a complicating pregnancy or fibroids. In a case of this nature the breaking-down cancer tissue is removed with the curette, the raw surfaces are seared with the Paquelin cautery, the lips of the cervix are closed with sutures or, if the disease has spread too far to allow this, a piece of dry gauze is packed against it. The vagina is then carefully sponged clean and ringed by a knife cut at a level an inch or more below the level of the growth. The vaginal walls are carefully dissected off up to the level of the cervix, and their edges sewed closely together so as to retain the gauze and prevent if possible any subsequent infection of the peritoneal cavity. Any bleeding points in the vagina are secured by ligature and the vagina is lightly packed with gauze. The instruments and gloves used in this part of the operation are discarded and the operation is finished through an abdominal incision as already described.

In any case in which it is probable that one must finish from above, ligatures and not clamps should be used in securing the uterine arteries, as the presence of the long clamp forceps in the vagina markedly increases the difficulty of any subsequent work through the abdomen.

After-Treatment.—After an abdominal hysterectomy, before the patient is taken off the table, and while still under the influence of the anæsthetic, a high enema of a pint of decinormal salt solution is introduced into the rectum, and if there is shock this is repeated every three to six hours. Nothing is to be given by mouth for six or eight hours, and then hot water in half-ounce doses with ten drops of lemon juice added is allowed every hour. If the stomach will retain it, half-ounce doses of hot broth or hot milk may be given at hour intervals. If the case progresses favorably, it is not necessary to begin to move the bowels until at the end of forty-eight hours; but if there is evidence of intestinal distention, salines should be started as soon as twelve hours after the operation. Many good operators give calomel or a saline an hour before the beginning of the anæsthetic. Rubinat or Apenta water in half-ounce doses followed by a half ounce of cool water, or drachm doses of Rochelle salt are to be given every hour for twelve doses. Three hours after the last dose an enema of an ounce of glycerin and eight ounces of water is given. In desperate cases with dangerous and increasing distention the author has seen brilliant results follow the enema recommended by Hardon[12] of an ounce of alum in a quart of hot water. Strychnine is often useful in one-fortieth to one-twentieth grain doses hypodermically. After the bowels have moved freely and when there is no distention, the food is to be cautiously increased, and the patient gets the treatment employed after abdominal operations in general. She can usually be allowed to lie on the back or side, as she may prefer. The urine is to be passed naturally if possible, but often has to be drawn for a few days by catheter. The catheter should be used for four days when it has been necessary to drain through the vagina.

After the *vaginal clamp operation* the patient is usually kept on the back with the knees supported by a firm pillow. At the end of forty-eight hours the keys are applied to the lower forceps and the catch is separated a quarter of an inch. The keys are then removed and the forceps is rotated gently and slowly about ten degrees in either direction while very gentle traction is made. If the forceps does not come away readily no force must be used. If the gauze is adherent, it is to be separated from the forceps by a blunt, flat instrument. When all the forceps have been removed the patient is kept quiet on her back for six hours, and then is allowed to turn on the side if she wishes. On the eighth day she is put in the Sims position and the dressings are carefully removed and renewed. The instruments used are a long-bladed Sims speculum, Pryor's trowel, and a dressing forceps. The gauze strips in the centre are removed first so as to loosen those next the vessels. When all the gauze has been removed the red, oozing, lymph-covered rectum and blackening lateral stumps are seen. These sloughing tissues smell bad unless kept dry by repeated and ample dressings of gauze. This gauze is to be renewed as often as a free discharge comes through it, which is usually every fifth or sixth day. Sloughs are not to be pulled off but must be allowed to separate spontaneously. Patients are usually allowed out of bed at the end of three weeks.

After abdomino-vaginal hysterectomy, or Werder's operation, the vagina is loosely packed with gauze until granulation begins and is then kept clean by irrigation with warm boric-acid solution.

The *complications* peculiar to the operation, met with during and after abdominal or vaginal hysterectomies, are mainly due to injuries to ureters, bladder, or intestine. The main causes of death are hemorrhage or sepsis, leading to fatal exhaustion or general peritoneal inflammation with intestinal atony. The supravaginal operation undoubtedly gives the most satisfactory finished result, but the recent observations of Broun[13] and others seem to prove that the chances of a secondary infection, possibly of a fatal character, are slightly less when the entire cervix has been removed. The statistics of mortality vary greatly, but in general, in the hands of properly skilled operators, it varies between four and eight per cent. The author's operations have shown a mortality of a little less than five per cent. for the supravaginal operation and five and a half for the vaginal. *Brooks H. Wells.*

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[1] Quoted by Fenger: Amer. Jour. Med. Sci., 1882, p. 18.
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[3] Kelly: American Journal of Obstetrics, September, 1900.
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HYSTERIA.—The disorder to which this name is given is evidenced by an almost innumerable variety of symptoms, which may be grouped in a general way into signs of increase, diminution, or perversion of the various nervous functions. In *hysteria major* convulsive and emotional seizures often occur with intervening signs called *stigmata*, especially including paralysis and anæsthesia, or the stigmata may appear alone. Hysteria is a psychosis. Post-mortem investigation gives no clew to the morbid process, and theoretical study of its nature has led, as yet, to little more than conjecture. The ancient view that a disordered uterus lay at the bottom of the trouble (whence the name, from *ὑστέρα*, uterus) has been long since discarded, and although the symptoms may be exaggerated, or even brought on, by disease of the uterus or its appendages, such disease is not an essential factor, the strongest proof of which lies in the fact that men, as well as women, suffer from hysteria. Whatever the exact nature of the disease, its seat must be regarded as the nervous system. It is generally considered that all parts of the nervous system—brain, spinal cord, peripheral nerves, and sympathetic—are implicated. The most marked symptoms are referable, however, to cerebral disturbance, and it seems justifiable to assume that the cortical structures are the principal sufferers from altered irritability. Most of the paralytic symptoms, for example, are best explained on the supposition of decreased irritability of the cortical centres, while the spasmodic symptoms allow of explanation in part on the ground of their exalted irritability, and in part on that of diminished inhibition. The psychical symptoms can, of course, be referable only to cerebral disorder.

Etiology.—Hysteria may exist as a primary neurosis, significant of degeneration, or it may be acquired. It appears commonly among females, but typical examples are found in the opposite sex. Briquet considered that fully half the women possess an impressionability differing little from hysteria. It is more frequent between the ages of ten and thirty, most frequent between fifteen and twenty, but may appear in infancy and also in advanced life. A most constant and important factor in the etiology is heredity, under which head must be included not only hysteria in the parent, but also other nervous and mental diseases. Extreme sensitiveness, irritability, emotional tendency, and allied traits in the parents indicate also a type of nervous organization in the family, which may lead to the development of hysteria in the individual. Other predisposing causes are, for example, ill-directed training, depressing influences, unhappy surroundings, desires ungratified, and all causes of continued anxiety and disquiet, especially if joined with excessive bodily fatigue. The advent of other disease may hasten the approach of hysteria, most frequently, perhaps, disease of the reproductive organs. Too much importance should not, however, be attached to coexisting disease of these organs; in many cases the coexistence is merely a coincidence, and in many the local symptoms are secondary to the general nervous disorder. The advent of menstruation and of the climacteric, as well as of pregnancy, may usher in the first signs. A mental or physical shock, a violent emotion or irritation, are common immediate and determining causes. Severe trauma, especially that resulting from falls blows, and railway collisions, is not an infrequent exciting cause. Many of the cases formerly classed under "railway spine" are now recognized as hysterical, and the former term has been largely replaced by traumatic neurosis, which includes traumatic hysteria. Predisposition is not essential, but in those cases in which the violence and duration of symptoms is out of all proportion to the violence of the trauma, the latter is probably only the excitant, not the fundamental, cause of the condition. In many of these cases the term "litigation neurosis" would be appropriate, inasmuch as the circumstances accompanying the suit for damages often play a greater part in the etiology than the original shock. While the disease is by no means confined to the upper class of society, it not infrequently appears there in young ladies whose comparatively aimless lives alternate between the excitement incident to balls, theatres, etc., and complete mental and physical idleness. This manner of life tends to the cultivation of the emotions and favors morbid introspection, while offering little opportunity for the exercise of will power. An irritability of the nervous system is thus produced which predisposes to hysteria.

Clinical History.—The disease in most cases is of so gradual growth that it is impossible to date its commencement. The patient inherits a neurotic tendency, which is fostered in childhood and youth by some of the predisposing causes already mentioned. It follows that, although the first decided symptoms, as paralysis or convulsions, may appear later in life, apparently on account of some trifling mental shock or bodily injury, the existence of the disease must date much farther back. Any or all the symptoms to be enumerated may appear in the given case, and in almost any order. In some cases the persistence of certain symptoms is a marked feature; in others the symptoms appear and disappear with great rapidity, without order in respect to locality or to sequence. The distinction between *hysteria major* and *hysteria minor* is largely one of degree, for both are characterized by exaltation and depression of nervous function with tendency to crises. In hysteria minor, however, the persistent symptoms do not extend beyond morbid sensitiveness, mental or physical, clavus, globus, backache, flushes and chills, while the crises are limited to emotional outbursts of moderate violence such as attacks of laughing and crying, followed by copious discharge of pale urine of low specific gravity. For convenience of description, the leading symptoms may be divided into disturbances of sensation, motion, circulation, secretion, and excretion, and of the mind.

Disturbances of Sensation.—Hyperæsthesia is one of the most constant symptoms of hysteria. When it is of a high degree the lightest touch causes signs of extreme distress, and even convulsive movements. When spread over a large surface the hyperæsthetic region is generally sharply bounded by lines which do not define the distribution of any particular nerves. These regions show no tendency to bilateral distribution, being often limited to one side of the body, and not infrequently bounded accurately by the median line. A common peculiarity of these tracts is to change their boundaries and situations, spreading gradually over one side of the body, disappearing in one place to appear in another, or passing from one side to the opposite. Circumscribed areas of anæsthesia, or of normal sensibility, may appear in the midst of an hyperæsthetic region. The sensitiveness is often limited to certain spots. Such spots are found most constantly over the vertebræ at varying heights, and on the scalp, but appear also on the neck, breast, abdomen, in the genital region, over the joints, and elsewhere. Hyperæsthesia of the larynx causes spasmodic coughing to be brought on by the least irritation, as the inhalation of cold air. The mucous membrane of the nasal, buccal, and faucial cavities, the conjunctiva, the meatus externus, and the tympanum may, any or all, be found hyperæsthetic, with exaggeration of the physiological reflexes. Spontaneous pains are common and may assume the character of superficial neuralgias, or appear to lie deeper, as in muscles, periosteum, or abdominal viscera. Hysterical patients are especially prone to headache and to the so-called clavus hystericus, a boring or burning sensation at or near the vertex, a symptom not more common in hysteria, however, than in neurasthenia and allied nervous states. An infinite variety of disagreeable, though not absolutely painful, sensations are complained of, often of the most vague and indescribable character, and again more or less typical, as the globus hystericus, and the sense of pressure in the epigastrium or over the chest, combined with a feeling of anxiety, or even the symptoms characteristic of angina pectoris. Sensitiveness and pain in the ovarian region (*ovarie*) are often found, generally on the left side. Pressure over this region sometimes produces a convulsive attack; and again, continued pressure is said to cut short such an attack when under way. The constancy of seat, together with the fact that the irritable spot rises and falls with the uterus before and after pregnancy (Féré), renders it probable that the irritability lies in or about the ovary rather than in the abdominal walls. Sensitiveness about certain joints (knee, hip, ankle, wrist), both with and without swelling, constitutes the "hysterical joint," a phenomenon which may be mistaken for more serious disease, but which generally disappears spontaneously, sometimes suddenly. Hyperæsthesias of the special senses are not rare. That of vision is shown by dread of light and of certain colors, and by hallucinations of sight. The auditory centres may be so irritable that all sounds are disagreeable, and that sounds are distinguished which are not audible in the normal condition. Tinnitus aurium, auditory hallucinations, and vertigo, resembling that of inner-ear disease, appear, the former frequently. Smell and taste may be abnormally acute. Certain odors and tastes agreeable to others may cause distress, and again the most offensive substances may be pleasurable. Hallucinations in these senses also occur. Psychical hyperæsthesia rarely fails; peculiar and excessive likes and dislikes are of every-day occurrence, and violent emotions, both pleasurable and the opposite, are excited by minimal stimuli. Anger, horror, dread, disgust, are produced by objects to others comparatively or quite inoffensive.

Anæsthesia.—All forms of sensation, general and special, may be impaired. The anæsthesia may rapidly change its boundaries, suddenly disappear, or remain for a long time stationary. It sometimes appears after convulsive attacks. Analgesia is most frequently noted, but all varieties of general sensation suffer, including the so-called muscle sense. Loss of "electro-muscular" sensibility is common, but not diagnostic. The anæsthetic regions are generally sharply defined, and vary from limited spots to large tracts. In hemianæsthesia the boundary is generally sharply drawn at the median line, back and front. Sometimes both sides of the body are anæsthetic in different degrees. In hemianæsthesia the special senses generally disappear on the affected side, and in a degree corresponding to the loss of general sensation. This form of anæsthesia is easily overlooked, owing to the patient being unaware of its existence; it should therefore be systematically sought for; if genuine, it proves an invaluable aid in diagnosis. Single extremities may be anæsthetic, or separate spots on the trunk, limbs, hands, or feet. The mucous membranes are apt to be included, and to lose their reflex irritability (sneezing, vomiting). Anæsthesia of the larynx is common. The bladder and rectum may lose their sensibility, as shown by the accumulation of fæces and urine without the patient's knowledge. The urethra and vagina may also take part. The blood-vessels are sometimes contracted over the anæsthetic areas, the prick of a pin being followed by less bleeding than normal. Anæsthesia of the special senses is apt to occur coincidently with anæsthesia of the skin about the organ of special sense affected. Visual anæsthesia is evidenced by retraction of the field of vision, central amblyopia, and loss of color perception. Ophthalmoscopic examination reveals nothing of note. Hysterical deafness has been long noticed, but less extensively investigated than hysterical blindness. The writer has found loss of hearing by the bone and impaired perception for high tones in a series of cases. Taste and smell may be affected, the loss being generally unilateral. The application of a magnet to the anæsthetic region either touching or within a few centimetres of the skin is followed in some cases by return of sensibility, general and special, and sometimes by a transfer of the anæsthesia to another part, most frequently to the corresponding region on the other side (transfer). In hemianæsthesia the entire disturbance may pass from one side to the other and in susceptible cases oscillate from side to side until equilibrium is reached. The time occupied by the transfer varies from a few minutes to an hour or more, becoming shorter with repetition. The same phenomenon has been brought about with other substances, as blisters, metals, or pieces of wood, and in certain cases the patient's expectant attention alone doubtless suffices.

Disturbances of Motion.—Spasmodic contractions appear in almost every part of the muscular system. They may be limited to one muscle or set of muscles, or be widely spread, as in general hysterical convulsions. The contractions are sometimes tonic, sometimes clonic; they may come in attacks, or last for a long time (contracture). They vary in severity from firm contractions, resisting all efforts to overcome them, to the slight twitchings popularly termed "fidgets." Between these degrees come the movements of hysterical chorea, which are generally confined to the face and neck. Spasms not occur only in the extremities, and in the muscles of the trunk, head, and neck, but in deeper-seated parts. The "globus hystericus" is caused by contraction of the muscles of the œsophagus, pharynx, or both, giving rise to the sensation of a lump rising in the throat. The tongue may be included in these spasms and be drawn upward, backward, or to one side. Peculiar sensations in the abdomen, as of a body rising from the uterine region to the stomach, or of something moving about in the abdomen, probably are caused in part by increased peristaltic movements in the intestines. "Phantom tumors" are produced by intestinal distention combined with spasm. Hysterical vomiting, which occurs both with and without loss of appetite, both after eating and while the stomach is empty, is another symptom of convulsive action in the digestive tract. Spasm of the bronchial muscles is evidenced by difficult respiration. Attacks of this nature are sometimes brought on by irritation of the diseased uterus (*asthma uterinum*, Jolly). Convulsive laughter and weeping are familiar symptoms of hysteria, both isolated and preceding or following severer convulsive attacks. Attacks of shrieking are not uncommon, and spasm of the glottis may even appear to threaten life by asphyxia. Spasmodic action of the sphincter vesicæ not infrequently causes retention of urine.

General convulsive seizures come on sometimes as a result of physical or mental shock, or of strong emotion, and again without apparent exciting cause. They are often preceded by peculiar sensations, as of suffocation, or of abdominal pain, and sometimes by a cry. The onset is generally gradual, and the patient is rarely injured by a sudden fall. Tonic spasms gradually ensue, involving a part or the whole of the body. Extreme opisthotonus may be reached and maintained for a considerable time, also emprosthotonus or pleurothotonus. The patient may gradually change from one of these positions to another. The consciousness is generally impaired, sometimes appears to be entirely suspended. The attack varies in length, sometimes persisting for hours. The tongue is rarely bitten, and stupor rarely supervenes, but pain and stiffness are complained of for some time after. Gesticulations, emotional language, and more or less purposeful movements are not uncommon. Although these convulsions cannot be called voluntary, the patient often has it more or less in her power to resist their onset, and is apt to postpone the seizure until a convenient occasion. The power of resistance lessens with the continuance of the trouble. A sudden shock may prevent or cut short an attack, and pressure on one or the other ovary may cause relaxation of the spasms.

Paralysis may attack any or all of the extremities. It may appear as hemiplegia, or as paraplegia, or may attack single muscles or groups of muscles. The face is commonly exempt, not being drawn to one side in otherwise complete hemiplegia. The degree of paralysis varies from slight impairment of power to complete loss of motion. The electrical reactions are not materially affected. The appearance and disappearance of paralysis are generally sudden, sometimes gradual. Change of seat is rapid and frequent in some cases; in others the same form persists for a long time. Contractures sometimes accompany and follow paralysis, and it has been claimed that organic changes (sclerosis) may result from persistent functional disease. Paralysis, like other hysterical symptoms, may disappear upon the application of powerful stimuli. Tremor is sometimes present in the head or extremities. Anæsthesia generally accompanies paralysis of motion, although the converse is less uniform. In general, disorders of motion are less frequent than those of sensation. Paralysis of the pharynx and œsophagus may necessitate artificial feeding. Paralysis of the intestinal muscles is evidenced by tympanites and obstipation. Paralysis of the vocal cords generally appears suddenly under mental excitement, and sometimes disappears in a similar manner. It is often most persistent, and when it is combined with lingual paresis the patient is unable even to whisper. The laryngoscope reveals nothing abnormal about the cords, but generally paralysis of their contracting muscles on one or both sides. The thyro-arytænoideus internus is often affected. Paralysis of the bladder is not infrequent. Paralysis of ocular muscles in hysteria is not common, but paresis of the levator palpebræ is frequently seen, causing a drooping of the lid, which is characteristic, usually bilateral.

Circulatory, Secretory, and Excretory Disorders.—Palpitation ensues in some cases upon slight exciting cause, and again, the heart beat is reduced to the minimal as in the cataleptic condition. Variations in the peripheral circulation are frequent and rapid. The pulse is sometimes small and tense, sometimes full and soft. The skin varies from cold and pale to red and hot. In the former case less blood than normal follows the prick of a pin, and the perspiration is apt to be lessened, increasing with the dilatation of the cutaneous vessels. The regions over which these changes take place vary from circumscribed spots to the half or the whole of the body. "Flushes" are common, and redness and heat of the head are liable to coexist with coldness of the extremities. Fainting is common, due probably to cerebral anæmia. Swelling of the extremities, with œdema, sometimes appears suddenly, to disappear as suddenly, without disease of the heart or kidney or other complication. These swellings are classed under the term angioneurotic œdema, and are sometimes quite persistent. The skin may be of waxy pallor, and may pit, or be dark colored and brawny. Gangrene does not follow. Most of these phenomena owe their origin probably to vaso-motor irregularities. Possibly similar changes in the cortex of the brain are at the bottom of some of the symptoms referable to that organ. Actual bleeding follows congestion in various localities. Menstrual irregularities are common. Increased or decreased flow of saliva has been noted, and the vomiting of large quantities of fluid without ingestion points to increase of gastric secretion. The urine varies in quantity from greatly increased (especially after convulsive attacks) to notably diminished. Cases of genuine anuria have been established. The presence of urea in the vomitus points to vicarious excretion. It seems probable that the difficulty, whether vascular or purely nervous, lies in the kidney itself, although spasm of the sphincter vesicæ may be also present (Charcot). Increased and irregular lacteal secretion has been noted, and more frequently leucorrhœa without local disease, particularly after convulsive seizures.

Mental Condition.—Hysteria occurs in persons of every grade of intelligence, and by no means implies deficient intellectual power. Lack of balance and of will power, however, is generally apparent even when combined with quick perception and excellent memory. The emotional side of the nature is generally disturbed; on the one hand, the least stimulus is sufficient to bring about an exalted state of happiness or deep melancholy, and on the other hand emotion may seem quite wanting, the patient exhibiting the utmost indifference to her surroundings. Extreme sensitiveness is common, the patient takes offence easily, and is easily made unhappy by neglect. In general such patients are extremely egotistical and selfish, and while demanding, directly or indirectly, the most extreme attention from others, fail to exhibit the least consideration for those about them. Lack of application is a common failing, yet once aroused the patient may show a persistence and untiring energy far in excess of that demanded by the occasion, or of that which a person of good judgment would display. These patients often persist in making themselves martyrs, and in drawing attention, directly or indirectly, to their peculiarly trying circumstances and sufferings. The regard for veracity is often diminished, and the desire for sympathy may lead to the most outrageous deceptions—a fact which has caused the name hysteria to bear with it a degree of opprobrium which it by no means necessarily deserves. Hysterical patients, especially hystero-epileptics, are prone to somnambulism, hypnotism, ecstasy, and allied conditions. The step from hysteria to insanity is often a short one and hard to define. Hysterical delirium leads to fixed delusions. Melancholy, mania, *folie raisonnante,* and even dementia may follow.

Hystero-epilepsy (for the analysis of which, as of all phases of hysteria, we are especially indebted to the efforts of Charcot and his pupils) is the severest form of convulsive seizure to which hysterical patients are subject. It is distinctly a symptom of hysteria, and in no way to be confounded with epilepsy when it assumes its typical form, although certain cases, in which hysteria and epilepsy coexist, may offer difficulties in diagnosis. The seizure is generally preceded by change in disposition, perhaps for some days, and more directly by an aura, abdominal or epigastric, which affords the patient time to seek a position of safety. The attack proper is divided into four periods: (*a*) the epileptoid, (*b*) the period of contortions and great movements, (*c*) the period of emotional attitudes, (*d*) the period of delirium. The (*a*) epileptoid period is generally ushered in by a cry, the consciousness is lost, the patient falls to the ground, the face is pale, the features are distorted. Tonic spasms ensue, affecting all extremities. Clonic spasms follow, resembling those of epilepsy. The face becomes tumefied and violet. The patient sometimes froths at the mouth and bites the tongue. A short period of relaxation follows, with coma. In the second period (*b*) various extraordinary positions are maintained for some minutes, with great force, for example, that of extreme opisthotonus. In this stage the respiration is not interfered with, and the face is not turgid. The great movements which follow are distinguished from the clonic spasms by their greater extent, and the non-rigidity in the parts affected. These movements may be executed by the whole of the body or by a part. Most characteristic are flexion and extension of the trunk, rapidly alternating, the forehead striking the knees on flexion, the head and back being thrown violently on the bed in extension. Such a movement may be repeated fifteen or twenty times. The next period (*c*) follows generally without intervening repose, the great movement, or the contortions, merging into the emotional attitudes. These attitudes, representing gayety, sadness, etc., seem to result from hallucinations, and to express a delirium of the imagination. The period of delirium (*d*) represents the more or less gradual return to equilibrium, and is analogous to the initiatory period. Sadness pervades this stage, in which the patient dwells on events of her past life with lamentations. After the attack, large quantities of pale, clear urine are voided. The duration of the attack proper, exclusive of the stage of delirium, varies from fifteen to twenty minutes, the epileptoid period lasting from one to three minutes, the period of contortions and great movements about the same, or a little longer, the period of emotional attitudes from five to fifteen minutes. The supervening delirium varies from a few minutes to a considerable time. Hystero-epileptics generally present marked constant symptoms, contractures, motor and sensory paralyses, notably hemianæsthesia, and the mental characteristics of hysteria are apt to be particularly well marked in these patients. The *ovarie* is commonly present, firm pressure over this spot during an attack causing complete relaxation and return of consciousness, to be followed by relapse into the previous condition on removal of the pressure. Other hysterogenic zones are found in various parts, as above and below the breasts, less constantly, however, than in the ovarian region.

DIAGNOSIS.—The diagnosis of hysteria from organic disease of the nervous system is of the greatest practical importance, and is in general not difficult, especially when the course of the disease is known. The predominance of subjective symptoms over objective disturbance is noteworthy. There is, in general, absence of such definite signs of organic disease as local atrophy, electrical change, pupil irregularities and loss of light reflex, of ankle clonus and the Babinski reflex, of bedsores and cystitis, as well as of facial, ocular, and bulbar paralyses. There may be rapid and complete change in seat and character of the symptoms, a nervous history and nervous antecedents. The presence of globus, clavus, ovarian and spinal tenderness, hemianæsthesia, segmental anæsthesia, aphonia, convulsive attacks, and characteristic contractions, assist in the differentiation of hysteria from most organic diseases with which it is liable to be confounded. Hysterical hemiplegia differs from the common form of organic hemiplegia in the exemption of the facial muscles, in the absence of spasticity, and in the sharp boundaries of the anæsthesia if present, whether occupying half the body, a single extremity, or spots of irregular distribution. The anæsthesia of organic cerebral disease is most marked at the extremities and shades off gradually as the trunk is approached; it is more apt to impair the power of recognizing objects in the hand with eyes closed (stereognostic sense, with its factors, spacing, localization, and posture senses) than the sense of pain, of touch, or of temperature. The latter are more often lost in hysterical anæsthesia, and the hysterical patient will often handle intelligently, and use with dexterity, an instrument which she states is not felt. This offers marked contrast to the hemiplegic, who states that the knife or pen is felt, but who neither recognizes its character nor uses it naturally.

Hysterical hemianæsthesia is easily recognized by its typical distribution, and by the fact that the special senses are generally involved to a corresponding degree. It is important to avoid mistaking the transient loss of power accompanying *myasthenia gravis* (pseudo-bulbar paralysis) for hysterical paralysis. The paralyses of myasthenia gravis are prone to appear in the latter part of the day, and are peculiarly liable to attack the ocular and bulbar muscles, regions ordinarily spared in hysteria. It must always be remembered that hysteria does not preclude the coexistence of organic disease, as tumor, abscess, or meningitis. Hysterical symptoms occurring in elderly women, not hitherto subject, should always suggest the possibility of malignant or other exhausting disease. The diagnosis should never be limited to hysteria till organic disease has been carefully excluded. Convulsions of hysteria are generally distinguishable from epileptic seizures by their longer duration, by the absence of the characteristic clonic spasms of epilepsy, and by the greater excursion of the movements. The hysterical patient rarely injures herself in falling, and only exceptionally bites the tongue or froths at the mouth. Stupidity rarely intervenes, but a large quantity of pale urine with low specific gravity is often voided directly after an attack. Doubtful cases are more apt to prove epileptic, and should generally be given bromide treatment. Aphonia, of hysterical origin, may be distinguished by the rapidity of onset and recovery, together with the absence of symptoms pointing to organic disease of the larynx. The diagnosis between hysteria and other functional nervous diseases is not so important, and the line is often hard to draw. The hysterical has many symptoms in common with the neurasthenic patient. The presence of paralyses, contractures, convulsions, hyperæsthetic regions, and of well-marked circulatory, secretory, and excretory symptoms, places the case under hysteria, the name *neurasthenia* applying to patients suffering from nervous exhaustion and irritability without the so-called hysterical stigmata. On the boundary line fall certain irritable, worn-out patients, prone to laughing and crying, and other lighter emotional symptoms. In such cases it is difficult and unnecessary to make an accurate classification. The essential peculiarity of the *hypochondriac* is his undue attention to, and anxiety regarding, his own condition. Either the hysterical or the neurasthenic patient may, therefore, suffer also from hypochondria.

PROGNOSIS.—Life is threatened only in the rarest instances. Patients have died with hysterical symptoms, but it is doubtful if hysteria itself can be said ever to be fatal. Radical cure of well-established tendency to hysteria, when primary and degenerative, is hardly to be expected, though separate attacks are likely to disappear spontaneously or under treatment. Attacks of hysteria with definite exciting cause, as trauma, or exhaustion, without predisposing tendency, promise more favorably than cases of the same severity resulting from hereditary tendency. Cure may be generally expected in such cases in a period varying from a few months to a few years. Litigation seriously delays recovery. In general, the longer the disease has persisted the worse the prognosis. This is especially true when convulsive attacks are present.

TREATMENT.—The early training of children predisposed by inheritance to functional nervous disease is important. Too great indulgence and solicitude are as bad on the one hand as severe punishment and ridicule on the other. Every means should be taken to cultivate the child's self-control, and for this purpose removal from its home will often be found beneficial, inasmuch as bad example is there added to faulty training. Physical development should be encouraged. Anæmia should be treated if present. Early marriage should not be encouraged, for it is as liable to aggravate as to lessen the tendency.

Given a case of hysteria once developed, the first aim is to remove the causes which foster it. Anæmia and debility must be combated; arsenic in small doses may prove of benefit, besides the ordinary tonics. The German Eisenzucker (ferrum oxidatum saccharatum) will be found an agreeable preparation of iron for persons of delicate digestion. Disease of the uterus and its appendages, when present, must be rectified, although scepticism is always in place regarding local disease as an etiological factor, and unnecessary manipulation of the genitals should be avoided. Flatulence, indigestion, and constipation should be treated. Atony of the alimentary canal may be benefited by nux vomica, strychnine, or quinine. If the presence of family and friends is believed to be deleterious, the surroundings should be changed. The patient should neither receive excessive sympathy nor be ridiculed as an imaginary sufferer. An endeavor should be made to gain the patient's confidence and rouse her to the systematic exercise of will power and self-control, not only regarding her symptoms, but also in the ordinary duties and disturbances of her life. Regular employment and physical exercise, such as bicycling or horseback riding, should be encouraged. Valerian and asafœtida will be found useful in spasmodic conditions, the latter especially in hysterical tympanites and colic. As a rule, neither bromide of potassium nor chloral will be found of sufficient benefit to justify continued use, though they must sometimes be resorted to for sleeplessness. Opium and alcohol are likewise to be avoided. To relieve individual attacks of pain by morphine is only to weaken the patient's own power of resisting pain, and perhaps to add a craving for the drug. Hyoscyamus, conium, and cannabis indica may be substituted. Good diet, cold baths, the douche to the back, massage, regular exercise in the open air, mental diversion, and avoidance of excesses are important. Electricity sometimes proves of value, especially the static current. Application of the magnet and of various metals, while of great physiological interest, as in the study of "transfer," will hardly prove of much therapeutic value. During convulsive attacks over-solicitude will tend only to aggravate and render them more frequent, excepting when the consciousness is entirely lost. The severer attacks can sometimes be cut short by a sudden shock, as pouring cold water on the face, and the memory of such treatment doubtless lessens the probability of recurrence; there are, however, many objections to this proceeding, and it will rarely be found advisable. The inhalation of ether or the subcutaneous injection of apomorphine may cut short an attack. Judicious neglect will often hasten recovery. Firm pressure over one or the other ovary will sometimes cause cessation of hystero-epileptic or other convulsion. Removal of the ovaries must be kept in mind as a last resort when disease of those organs is present. Nutrition should be kept up during cataleptic conditions, rectal alimentation or the stomach tube being resorted to if necessary. In obstinate cases, especially when malnutrition exists, after other methods have been tried in vain, it will be often advisable to adopt the plan (perfected by Mitchell) of seclusion, rest, massage, electricity, and full feeding. *George L. Walton.*

IBIT, bismuth oxy-iodo-tannate, a close relative of airol, bismuth oxy-iodo-gallate, is an odorless, tasteless, fine, greenish-gray powder. It is permanent in diffuse light, but in direct sunlight or in contact with water or animal fluids slowly decomposes with the liberation of iodine. This change is more rapid with warm water. Ibit is insoluble in ordinary solvents, but dissolves in acids or alkalies. It is used for wounds as a dusting powder, salve, or lotion. *W. A. Bastedo.*

ICHTHALBIN, ichthyol albuminate, is an odorless, almost tasteless, fine grayish-brown powder, insoluble in water and acid solutions, and soluble in alkalies and the intestinal fluids. It is prepared by adding ichthyol to fresh albumin and washing the resulting precipitate till it is free from ichthyol. It sets free in the tissues ichthyol, of which it is said to contain seventy-five per cent.

On account of its antiseptic and stimulating properties it has been used by Mack, Binder, Martin, and others internally for gastric and intestinal fermentation and for enteric fever. Sack says it sets free ichthyol in the intestine, but not in the stomach. It is claimed to be neither irritating nor toxic. Locally it may be applied in powder form. Binder uses it by insufflation for gonorrhœal or catarrhal vaginitis, endometritis, or erosions of the cervix. For chronic hypertrophic rhinitis it may be used as snuff two or three times a day. Mack obtained good results in eczema and furunculosis from the internal dose of 0.12–0.3 gm. (gr. ij.–v.) three times a day. Rollay places the dose at 0.3–0.7 gm. (gr. v.–x.) for a child of one year, while Homburger considers 0.1–0.2 gm. (gr. iss.–iij.) sufficient. No untoward effects were noticed from administering 0.5 gm. (gr. viij.) three times a day to a five-months-old child.

W. A. Bastedo.

ICHTHARGAN, ichthyol silver, silver thio-hydrocarbosulfonate, is a brown, odorless, amorphous powder of neutral reaction, containing thirty per cent. of silver and fifteen per cent. of sulphur. Its odor is wanting, or slight, suggesting chocolate, and it is somewhat sternutatory. It is easily soluble in water, glycerin, or dilute alcohol, slightly soluble in ether or chloroform, and insoluble in absolute alcohol. On exposure to light it is slowly decomposed, so must be kept in dark bottles. It is precipitated by sodium chloride or albumin, the latter precipitate dissolving in excess of albumin.

Aufrecht showed this drug to be more strongly antagonistic to anthrax, gonococcus, and other bacteria than is silver nitrate. In 0.3–0.5-per-cent. solution it prevents the decomposition of meat, bouillon, etc. With frogs, guinea-pigs, rabbits, and dogs it is much less toxic than silver nitrate. It is also more penetrating. Lohstein uses it in gonorrhœa as an irrigation in 1 to 4,000 to 1 to 2,000 strength. Leistikow considers its results in gonorrhœa remarkable; he uses a 0.02 to 0.2-per-cent. injection. For posterior urethritis Fürst employs an instillation of six to ten drops of three-per-cent. solution by Guyon's urethral syringe. As a prophylactic following suspicious coitus he instils three or four drops of a ten-per-cent. solution. It is said to be much less irritating than silver nitrate, and to be followed by no desire to urinate. Unna says that, unlike silver nitrate, it does not favor granulation, but favors rather the production of epithelium. The best results are obtained in clean ulcers and in old hard ulcers with callous margins after the horny layer has been removed by salicylic plaster mull. It is a strong astringent for indolent, œdematous, or hemorrhagic granulations. Falta uses a half to three per cent. solution for granular conjunctivitis. *W. A. Bastedo.*

ICHTHOFORM is a blackish-brown, amorphous, almost odorless and tasteless powder, resulting from the action of formaldehyde on ichthyol. It is insoluble in all ordinary solvents. Aufrecht has made a comparative study on bacteria and animals, especially frogs, rabbits, and dogs, and finds it to have a greater antiseptic power than iodoform and analogous compounds, and to be comparatively innocuous. Goldmann uses it locally for endometritis in ten-per-cent. glycerin mixture on tampons, and as a deodorizer in ozæna. Internally he employs it in atonic or functional digestive disorders. Five grains (0.35 gm.) may be given every three hours for acute gastro-enteritis and intestinal tuberculosis, in which conditions it is highly recommended. Polacco employs 0.5 gm. (gr. viij.) in capsule up to twelve capsules a day for enteric fever. It has no action on the nervous system, and its continued use in large dose is said to be without effect on the kidneys. In conditions of indicanuria with headache and malaise, its administration is quickly followed by disappearance of the indican from the urine and the relief of the symptoms. On account of its irritating properties in vaseline mixture, Unna prefers it made up with zinc ointment in one-per-cent. strength as an application in eczema capitis of children, psoriasis, eczemas of seborrhœic origin, and in pityriasic forms of eczema. As its hardening powers lead to superficial necrosis, it can be used only in affections which tolerate the desquamation of the horny layer. *W. A. Bastedo.*

ICHTHYOCOLLA. See *Isinglass.*

ICHTHYOL.—This is the trade name of a compound described as ichthyo-sulphonic acid in combination with ammonium. It is obtained by the distillation of a bituminous mineral deposit of the Tyrol, which contains an abundance of the fossil remains of fish and other marine animals. During dry distillation there passes over, between 100° and 225° C., a crude volatile oil. This is treated with an excess of concentrated sulphuric acid, which forms ichthyo-sulphonic acid, and this is precipitated by the addition of brine. The product, in addition, contains an uncertain percentage of unchanged oil, which cannot be removed without producing decomposition of the whole compound.

Ichthyo-sulphonic acid forms salts with ammonium, sodium, zinc, lithium, calcium, iron, silver, and various other metals, but the ammonium salt is that generally understood by the title ichthyol.

Ammonium-ichthyol-sulphonate, $C_{28}H_{36}S_3O_6(NH_4)_2$, is a thick, brownish fluid, with a smoky bituminous odor and taste. It is soluble in water, oil, glycerin, and a mixture of alcohol and ether. Its virtues are ascribed to the large amount of sulphur that is present, about sixteen per cent. It has a great affinity for oxygen and is a powerful reducing agent. It is stated to be an active germicide and to be free from any toxic action, but an instance is recorded in which the applications of one part of ichthyol to two parts of glycerin, to the curetted surface of the uterus, produced very alarming symptoms. The patient complained of the taste of the drug, tachycardia, and depression, and remained prostrated for twelve hours.

The therapeutic value of ichthyol depends upon three factors: its antiseptic action, a contractile effect which it exerts on the vascular system, and its reducing property.

It was introduced in 1883, by Unna of Hamburg, as a remedy for the treatment of various forms of skin disease. He described it as the remedy *par excellence* for acne. He advised fifteen drops twice a day internally, and a ten-per-cent. lotion to be painted on the affected parts at night; each day the lesion was to be bathed with hot water and ichthyol soap. In eczema and other forms of skin disease he advised it to be used more cautiously and in weaker solutions. In all these conditions its internal administration is also advised, as it is supposed to possess valuable alterative properties, which assist its local action. Ichthyol has come into very extensive use for all forms of skin diseases, and for the removal of the product of inflammatory processes, in chronic rheumatism and in cases of enlarged glands. In skin diseases it is applied as an ointment of the strength of five to ten or fifteen per cent. A varnish of ichthyol is a favorite method of using the drug. It is made of ichthyol 10 parts, starch 40 parts, solution of albumin 1 part, and water to 100 parts. The starch is mixed with the water, the ichthyol is then well rubbed up with it, and lastly the albumin is added. For inflammatory deposits stronger preparations are employed; ointments containing fifty per cent. may be used, or a mixture of ichthyol and glycerin is applied and the part is covered with lint and bandaged. Ichthyol plasters and ichthyol wadding may also be obtained.

The remedy has not been much used in general surgery, but in gynæcology it is a favorite application in all uterine and vaginal inflammations. It may be applied in a glycerin solution, or in its pure state on tampons, or medicated pessaries may be introduced after antiseptic and astringent douches have been used. When gonorrhœa is a factor the drug is thought to be especially beneficial. It has also been employed in inflamed states of the prostate gland, a ten-per-cent. solution being injected into the rectum.

In a paper presented at the Fourth International Medical Congress, Unna dwelt upon the value of ichthyol in the treatment of leprosy. His conclusions were: (1) Lepra tuberosa, even of universal extension and of more than one year's standing, can be cured; (2) the cure can be effected in a comparatively short time by the energetic internal and external employment of reducing remedies; (3) among these may be specially recommended ichthyol, chrysarobin, pyrogallol, and resorcin; the only one of which that can be administered internally, for a length of time, without danger, is ichthyol. He advised the application of a fifty-per-cent. ointment, and also the internal administration of fifteen to twenty-four minims (1.0 to 1.6) during the day.

Internally ichthyol is administered in pill form in capsules, the dose being up to twenty minims (1.3) daily for an adult. The dose for a child of two years is given as two minims (0.13) daily. *Beaumont Small.*

ICHTHYOSIS.—DEFINITION.—Ichthyosis is a congenital cutaneous deformity in which the skin is dry and rough and the epidermis thickened and scaly.

ETIOLOGY.—Almost all observers agree in regarding ichthyosis as a congenital disease, and the arguments in favor of this view are: That the disease commences early in life and endures throughout life, is only temporarily benefited by treatment, and immediately recurs on the cessation of treatment; that the disease is not inflammatory, as infective and toxic diseases are, but acts more like an anatomical deformity; that it is often a family disease, two or more brothers or sisters being frequently similarly affected, and even when the immediate family is free, more distant relatives may be found afflicted.

It is hardly necessary to draw attention to how characteristic this skipping over individuals is in hereditary affections, one or two members of one branch of a family and one or two of some other branch being picked out, the rest escaping. Nevertheless it must be admitted as remarkable how frequently cases of severe ichthyosis are reported in which the parents are said to be perfectly healthy, and this has been noted even when several of the children have ichthyotic skins.

An objection has been raised to calling ichthyosis a congenital disease, because it usually does not appear until the second or third year of life or even later. This, however, is not a valid objection, because ichthyosis agrees exactly in this particular with other congenital deformities. Nævi, for example, although certainly congenital, frequently do not appear until a considerable time after birth; not, indeed, until the gradual development of the affected individual or the growth of the lesion itself brings the blemish to view.

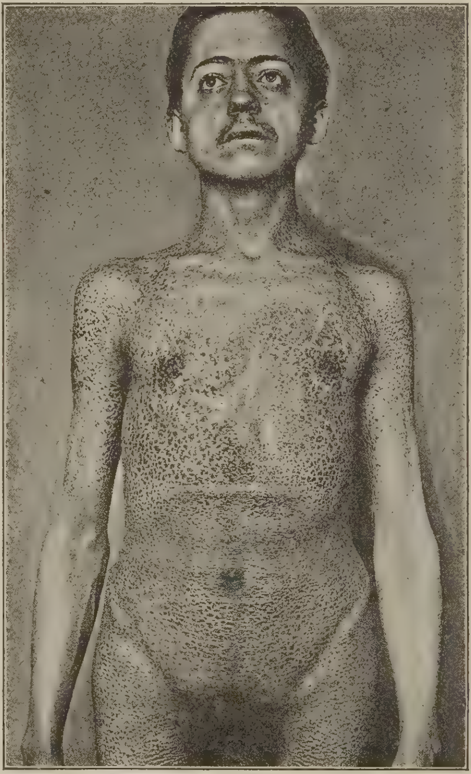

FIG. 2786.—Ichthyosis. (From A. Neisser's "Stereoscopischer medicinischer Atlas.")

Undoubtedly ichthyosis depends in a great measure on defective action of the sweat and sebaceous glands. Three of its features point decidedly in this direction, viz.: the dryness and lack of unctuousness of the skin; the improvement of the symptoms during the summer months when the sweat glands are most active; and the tendency to the localization of the disease in those parts where the sweat and sebaceous glands are least active, as on the extensor surfaces of the limbs, leaving the articular folds, such as the bend of the elbows, the axillary, inguinal, and popliteal folds, unaffected.

Although ichthyosis is an hereditary and congenital affection, yet it probably may be accentuated by diseases which are not in their true sense hereditary. Syphilis is not in the true sense of the term an hereditary disease. What we call hereditary syphilis is an "infective disease" caught congenitally. The way that syphilis, for instance, may possibly accentuate ichthyosis is shown by two cases reported by Gaston and Emery. The father of these children had a slight ichthyosis and also had syphilis. The children acquired syphilis congenitally, and became after birth markedly ichthyotic. Besides ichthyosis, however, the children had microsphygmia, and the authors entertained the opinion that the small pulse was owing to a generalized, congenital, syphilitic arteritis, and that this affection of the arteries so interfered with the nutrition of the fœtus as to accentuate the hereditary tendency to ichthyosis.

Recently Edward Fournier has collected from the literature nine cases, and has added one of his own, in which patients having hereditary syphilis also had ichthyosis. The author clearly states, however, that he does not believe ichthyosis to be a symptom of hereditary syphilis, but explains the coincidence by the theory that hereditary syphilis is at times one of the causes of degeneration in the individual, and that ichthyosis is a symptom of degeneration.

Interesting, particularly in its connection with treatment, is the relationship between defective development of the thyroid gland and ichthyosis. As one of the symptoms of cachexia strumipriva is a rough dry skin; a mistake in diagnosis might easily occur, or defective action of the thyroid gland might accentuate an already existing ichthyosis.

SYMPTOMS.—As ichthyosis is a congenital deformity there are necessarily all grades of it, from almost inappreciable manifestations up to disgusting monstrosities. Dryness of the skin and desquamation are, however, never absent in ichthyosis, and in fact in the most attenuated form of the disease, in xerodermia, extreme dryness of the skin, a very fine desquamation, and obstruction with epithelial cells of the pilo-sebaceous orifices are the only symptoms present. It is this last symptom, the accumulation of epithelial cells about the points of emergence of the hairs, that gives those having ichthyosis their "goose-flesh" appearance. This same permanent "goose-flesh" appearance constitutes the disease called keratosis pilaris, and it is because the same appearance is produced by the same kind of plugging of the same orifices, and also because the favorite situation of both keratosis pilaris and ichthyosis is on the extensor surfaces of the upper arms and thighs, that some authors regard keratosis pilaris, when it exists alone, as constituting the very lightest form of ichthyosis, even lighter than xerodermia.

Of the two symptoms, dryness and desquamation, Thibièrge considers dryness the more essential, even thinking dryness without desquamation often indicative of ichthyosis; therefore he would classify congenital permanent anidrosis as a form of ichthyosis, and this for the following reasons: In both diseases the skin is unusually dry, both are congenital, both occur in families as hereditary diseases, and some members of the same family may have anidrosis while others have ichthyosis. He thinks that many cases of ichthyosis which are supposed to develop during adolescence or later, are simply cases in which anidrosis was at first the sole symptom and which remained comparatively unnoticed, the more disagreeable symptom of scaliness supervening later.

Apart from the two general characteristics of dryness and a tendency to adhere and form masses, the superficial epithelium in ichthyosis shows many variations. It is sometimes powdery, and the cheeks for example may look as if dusted with white face powder; this constitutes a variety of the pityriasis simplex of some authors. This form of ichthyosis when more marked shows a diffuse granular coating, chalky and white, which is particularly apt to show itself on the outer surfaces of the upper and lower extremities. Instead of the granular powdery condition there may be scaling, and the scales may be clear gray or grayish-black, thick or thin, lustreless, hard or soft, but as above stated they frequently show a tendency to adhere with their flat surfaces tightly to one another, sometimes forming thick, uniform, lamellated, corneous deposits. When the epidermis accumulates in thick horny masses as it does in ichthyosis hystrix, pigment may develop in it, which may be a dirty green, a bright green, dark green, or greenish-black. The green may be so bright as to be startling, even seeming to have been artificially applied. The edges of the scales may be separated from one another by little furrows, or they may overlap like fish scales. Sometimes the surface of the skin looks like the finely crumpled tissue paper called crêpe paper used for lamp shades, where the ridges run in every direction, crossing one another and dividing the surface into a vast number of quadrilateral areas. The wrinkled epidermis in such cases looks as if too large for the cutis. Sometimes instead of there being ridges there are fine shallow cracks, passing through the superficial layers only. These cracks fill with dirt and, just as under the finger nails, this dirt assumes a dirty greenish-gray color, marking the skin off into lozenge-shaped areas by a dirty greenish-gray network. The lines may crack down deeper than indicated above, and the superficial epidermis may be broken and upcurved along the edges of the enclosed lozenge-shaped areas resembling the bark of some trees. The surfaces of these lozenge-shaped areas may glitter and reflect light like the facetted skin of some reptiles. Sometimes the surface looks unnaturally smooth and polished, with lines running across it at all angles, as if the surface had been varnished or had collodion poured over it, and had cracked in the drying.

Frequently the skin does not crack, but has running across it a vast number of criss-cross furrows dividing the surface in the same way into quadrilateral or irregular areas. These furrows are really the natural markings of the skin exaggerated, and are frequently chalky white and powdery; in such skins if the finger nail be drawn sharply across the surface it will leave a chalky white, crumbly, permanent mark.

Sometimes the papillary layer of the skin is hypertrophied, and when this occurs, and corneous masses or spines are formed over them, it gives rise to one of the varieties of ichthyosis hystrix. Another variety of such horny spines is formed by a great accumulation of the epithelial cells projecting from the pilo-sebaceous orifices, constituting the keratosis pilaris above named; this occurs generally on the extensor surfaces of the arms. Ichthyosis hystrix is never universal, although it may occur over large tracts of the skin. Usually it occupies only certain regions, while the intervening skin is xerodermatic. A child at present under treatment in the University Clinic has ichthyosis hystrix only on the ankles, while other regions show several different varieties of ichthyosis. This condition of ichthyosis hystrix, literally "hedgehog, fishy disease," is considered particularly undesirable in a bed-fellow.

The true skin may be atrophied, tightly stretched, and thin, and the subcutaneous fat layer may be thin and poorly developed.

The face is frequently unaffected except by a transitory powderiness, a pityriasis. The palms and soles are dry and powdery but not scaly, with the furrows more marked and more numerous than normal, and this condition may remain after treatment has improved the skin in every other locality.

The hair is frequently normal, of good color, lustre, quality, and quantity, but it may be dry, frail, and thinly scattered, constituting an expression of the same fault of development that gave rise to the ichthyosis. Sometimes there is nearly complete alopecia, even the eyebrows and eyelashes being almost entirely absent (Thibièrge). The nails may be strong and in every way normal. They may, however, be thin, brittle, and either transversely or longitudinally ridged, or there may be an accumulation of dry, brittle, corneous substance under the nails.

These patients sometimes give off a flat, stale, penetrating, disagreeable odor, such as is met with in other cases of generalized hyperkeratosis with maceration of the epidermis, as in Darier's disease for example (Thibièrge).

Usually the only subjective symptoms of ichthyosis are itching and a sensitiveness to cold; chilly feelings being experienced on the slightest lowering of the atmospheric temperature.

A patient usually presents examples of a number of the conditions enumerated above; for instance, the hair may be good, but the scalp is usually in a condition that cannot be distinguished from dry seborrhœa. The outer surfaces of the arms and thighs and the skin of the trunk may be dry and scaly and criss-crossed with furrows, and studded with dry papules that look like "goose flesh." The buttocks and upper portions of the thighs may be covered with "crêpe-paper" skin. The roughness of the skin increases down the extensor surfaces of the thighs until over the front of the knees one finds immense corneous masses. Below the knees the skin may be tightly stretched over the tibiæ, smooth, shiny, and with markings on its surface dividing it off into small quadrilateral areas.

Course and Duration.—Usually ichthyosis does not become appreciable until the second or third year of life, although cases have been reported in which the malady was apparent at birth or shortly after. The first symptom, according to Peukert, is the appearance of keratosis pilaris that shows itself on the extensor surfaces of the extremities in earliest childhood in these individuals. It is simply this early appearance of the keratosis pilaris and its greater development later in life that distinguish it at all from the ordinary form of keratosis pilaris. Ordinary keratosis pilaris of moderate development is so common later in life, especially at adolescence when the lanugo hairs begin to sprout more vigorously, that it is practically a normal condition. Ichthyosis continues to grow more marked from two or three years of age until adult life, when it may remain stationary or subject only to the mutations of the seasons, becoming severe in winter and milder in summer, till the natural dryness and harshness of the skin of old age again accentuate it. In summer, in fact, the plates, scales, and fluffy epidermis may all fall off as a "moulting," leaving the skin almost normal. Sickness and a lowered condition of health may also increase the dryness and harshness of the skin, and there is reason to believe that inactivity or absence of the thyroid gland can contribute decidedly to the severity of the symptoms. The symptoms of ichthyosis may disappear completely after one of the eruptive fevers, measles for instance (Joseph), only to reappear in a short time, however. This same amelioration may also occur during pregnancy.

Quinquaud has reported a case in which the patient got an ichthyotic skin following a generalized eczema of two years' duration. He says that such acquired ichthyotic states may after a time disappear. It is doubtful, however, if such ichthyotic states as described by Quinquaud should be included in the disease ichthyosis at all.

Unna and Tommasoli believe that ichthyosis is an acquired disease that has its time of onset, development, and disappearance, but this view finds very little support among other observers.

Unusual Symptoms and Course.—The flexures of the articulations, particularly the axillæ, the bends of the elbows, the groins, the scrotal thigh folds, and the poplitea are usually unaffected. In fact, Georges Thibièrge would make the freedom of those localities a sharp diagnostic feature. Recently, however, a number of cases have been reported in which one or several of these localities have been affected, and there happen just now to be in the University Clinic two patients in whom the axillæ, the groins, the scrotal thigh and vulvar thigh folds respectively, and the politea are affected, as shown by the presence of pityriasis. In both patients there is an eczema of the upper extremities that involves the bends of the elbows, making it impossible to say whether these are ichthyotic or not. The appearance and stubborn character of the eczema, however, would lead one to infer that the condition is also present there. Joseph has reported a case in which only the flexures were affected. Usually ichthyotic patients do not sweat, but Peukert thinks the dryness of the skin is in some cases not due to lack of perspiration, but to an increase of evaporation from the more extensive cutaneous surface of these people. In some instances there is vicarious sweating of certain regions as of the face for example (Goldzieher), or of other regions not implicated in the ichthyosis, as the axillæ, or the palms and soles. This sweating may be abundant. The mucous membranes are rarely affected in ichthyosis, unless the susceptibility to catching "colds" and to bronchitis be looked upon as the particular way they show their inherent weakness. There are atrophic forms of the disease, which Hallopeau considers simply an exaggeration of the form in which the skin is like crêpe paper. The skin is very thin and has little elasticity, so that when pinched it retains the impress of the fingers for a long time. The skin may appear too large for the patient, or on the contrary it may be too small, not permitting the closure of the eyelids, exaggerating the cutaneous folds, especially in the movements of the facial muscles, and impeding the flexion and extension of the fingers. In two of the cases so reported the skin seemed glued to the subjacent aponeurosis. Kaposi has shown a case which he called ichthyosis hystrix pterygoides s. plumiformes, in which there were hundreds of little growths from 0.5 to 1.5 cm. long that looked like feathers. These growths consisted of a central core of connective tissue with tufts of cornified epithelial tissue depending from them. The patient was a girl six years of age and the palms and soles were thickened, cracked, and warty. This case stands alone in literature, and it is not at all certain that it should be included among the ichthyoses.

Those having ichthyosis and those that are scrofulous have in common a tendency to inflammation of the respiratory tract, and besides that, Unna has noted with great particularity in one of his cases an unusual growth of hair down the cheeks in front of the ears. An unusual growth of fine downy hair in this situation was considered by the late Professor Horner, of Zurich, a symptom of scrofula.* A little girl suffering from ichthyosis, and at present attending the University Clinic, has quite a little beard of fine long hair growing down in front of each ear.

Diagnosis.—The first disease to be sharply differentiated from ichthyosis is nævus linearis, and this is not because there is any great similarity between the diseases, but because some writers persist in describing nævus linearis under the name ichthyosis hystrix. Nævus linearis is a warty congenital disease, in which the warts are frequently covered with horny masses, but here the similarity ceases. Nævus linearis occurs in lines or in localized areas, and is usually asymmetrical, and the skin between the patches or lines is absolutely normal. In ichthyosis the disease is symmetrical, and almost always the whole skin is affected, with the exception of the folds of the articulations. Another good point of differentiation lies in the fact that nævi, nævus linearis included, have generally a buff or a slate-colored pigmentation, and the pigment lies in the connective tissue of the skin, usually in the affected papillæ, while if there is a black or other color in ichthyosis, it looks more like dirt in the horny layers or pigment in the epithelium, rather than like pigment in the papillæ or in the true skin. In ichthyosis the palms and soles are almost always unnaturally dry with a powderiness of the surface, while in nævus linearis the palms and soles are normal, when not directly the seat of the nævus, which they rarely are. Furthermore nævus linearis does not attack several members of a family, but occurs irregularly here and there throughout a community; in other words it is not a family disease.

There is another disease, however, which is hereditary, which occurs in families, and which consists of an exaggerated development of the horny layer of the skin. This disease, keratoma hereditarium palmare et plantare, it seems desirable to keep separate from ichthyosis. This is all the more difficult to do because, besides the above points of similarity with ichthyosis, there is also in ichthyosis thickening of the horny layer of the palms and soles. In keratoma, however, the thickening is limited sharply to the palms and soles, and there may be increased action of the perspiratory glands of the affected surfaces. It therefore lacks the generalization of ichthyosis and also the dryness, two important features. Furthermore, in keratoma the thickening of the horny layer of the palms and soles is frequently much greater

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* He used frequently to say "they, the scrofulous, all wear a beard."

EXPLANATION OF
PLATE XXXIII.

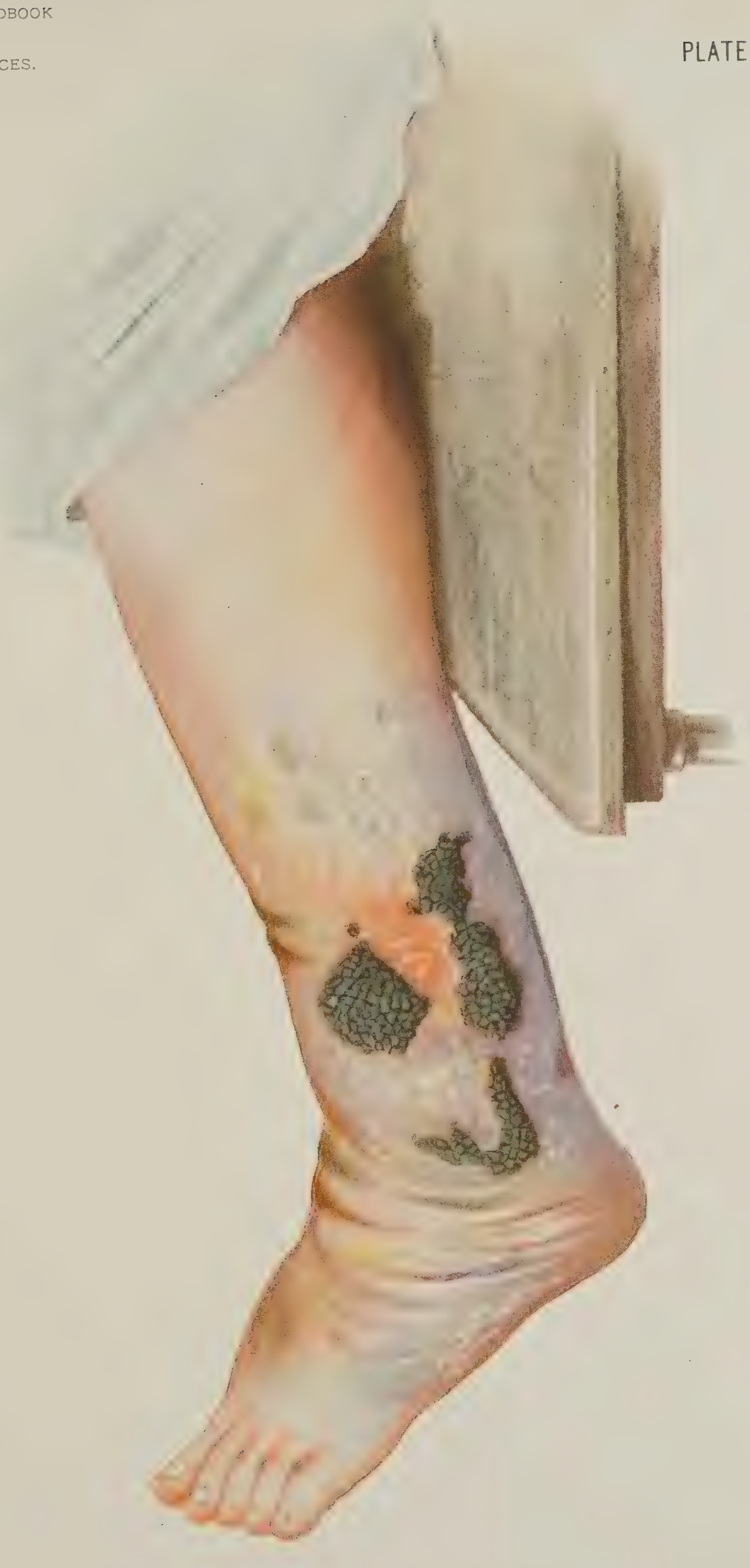
EXPLANATION OF PLATE XXXIII.

Dr. Douglass W. Montgomery's Case of Ichthyosis Hystrix.

The faint redness, the swelling, and also the violet hue in the neighboring skin seen in the plate were all due to an accompanying dry eczema.

The patches of thick green crusting were caused by epithelial masses covering the papillomatous skin, and constituted the ichthyosis hystrix. It was only on the ankles that the child had the papillomatous or hystrix variety of ichthyosis. In other situations, as on the upper parts of the legs, on the thighs, trunk, upper extremities, face and scalp, the ichthyosis was of other types.

PLATE XXXIII.



ICHTHYOSIS HYSTRIX.

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than even in the severest forms of ichthyosis. Joseph suggests that this keratoma may really be ichthyosis, in which a "moulting" process similar to that which takes place in some patients every summer, has taken place in utero, over all the surface excepting the palms and soles, leaving those parts alone affected.

The atrophic form of ichthyosis resembles somewhat the lesions found in the skin in some cases of scleroderma. It differs from scleroderma, however, in the absence of induration and of interstitial cicatrices, and also in the fact that it does not progress.

There are a number of desquamative inflammatory diseases of the skin, such as psoriasis, pityriasis, exfoliative dermatitis, and the dry eczemas, which differ from ichthyosis both in their course and in the fact that they are accompanied by inflammatory symptoms.

Georges Thibièrge at one time demonstrated a case as ichthyosis in which there were immense irregular horny masses distributed symmetrically in various regions of the body, but principally on the face and on the palms. There was almost no hair on the scalp. The buccal and nasal mucous membranes were thickened and furrowed, and there was a grayish infiltration in the superficial layers of the centre of each cornea. Latterly he has concluded that this case was analogous to one in which Giovannini had found the epidermal alterations principally about the orifices of the sweat glands. As the affection was congenital he gave it the name congenital disseminated porokeratosic hyperkeratosis, instead of ichthyosis.

For the diagnosis between ichthyosis and ichthyosis fœtalis the reader may consult the article on this latter subject.

Those who are much reduced by some chronic disease or by old age often have a fluffy scaliness of the skin. This is distinguished in the former case from ichthyosis by the fact that it develops and disappears with the development and disappearance of the cachexia.

A number of diseases of the nervous system are accompanied by atrophy and desquamation of the skin similar to ichthyosis. These ichthyotic states are distinguished from ichthyosis by their occurrence only on the skin supplied by the affected nerves.

PATHOLOGIC ANATOMY.—The principal lesion found in ichthyosis is a hyperkeratosis of the superficial layers of the epidermis, with atrophy of the deeper layers. The papillary layer is less developed than normal. The muscle bundles are hypertrophied. The keratosis pilaris can be seen to be due to plugs of cornified epithelial cells in the pilo-sebaceous orifices. Thibièrge says the orifices of the sudoriparous glands are free, but the sweat glands themselves and the sebaceous glands are frequently atrophied and cystic. The hair follicles may disappear and the hairs may atrophy. The papillary layer and the superficial layers of the derma show evidences of inflammation, which, however, are nothing more than one would expect from the irritated condition of the skin.

There is a question whether the green color developed in the epithelium in ichthyosis hystrix is true pigment, or dirt caught in the interstices of the epithelium. In the child at present under treatment in the University Clinic the green color is quite vivid, but when the epithelium in peeled off, as it can be in masses, the color is seen to be very superficial. It must also be remembered that when dirt is allowed to accumulate under one's nails, it has the same dirty olive-green color as in ichthyosis hystrix.

TREATMENT.—As ichthyosis is a congenital disease and permanent, all treatment must be directed not toward a cure, but to an amelioration of the condition. Much can be done for these patients, and in many ways, but everything of course is temporary, as they relapse as soon as remedies are withdrawn. Residence in a hot climate would be beneficial, as a spontaneous amelioration takes place in warm weather; but, of course, for many patients this is impossible. Frequent hot baths bring about the same result by increasing the activity of the sweat and fat glands, and in fact hot baths are indispensable in any plan of treatment. If a quick temporary effect is desired, jaborandi or pilocarpine may be given on account of their action on the sweat glands, but of course their continued administration would not be advisable.

Besides pilocarpine and jaborandi the internal use of many remedies has been advised, but they have very little effect on the malady, with the exceptions perhaps, of cod-liver oil and arsenic. Sulphur, the balsams, mercury, and many other drugs have been recommended but have been found to be of no avail. In some instances it is rational to suppose, and is by many believed, that arsenic in small doses does good. Arsenic in the form of Fowler's solution may be given in cod-liver oil emulsion.

As some cases of ichthyosis have been reported in which the thyroid gland has been found much diminished in size, and as roughness and desquamation of the skin are symptoms of cachexia strumipriva, it naturally follows that thyroid extract may be given with some hope of success.

Ehrmann, following out the idea suggested by Tommasoli that ichthyosis is due to an autointoxication, gave menthol internally in one case. He reported that under its influence the desquamation ceased, but the criss-cross lines persisted.

External treatment is of course what one must rely on. Hot baths, soft soap, and a good nail brush to get rid of the superfluous epithelium, and after the bath the inunction of a lubricant well rubbed in to assist in maintaining the skin soft and supple, constitute the principles of treatment. The hot baths must not be given too frequently and their effect on the patient must be watched, as in some cases they are debilitating. The choice of the lubricant is also not a matter of indifference; for instance cod-liver oil is acknowledged to be one of the best softeners of epithelium we have, yet its odor makes the patient more disagreeable to a larger circle of his acquaintance than the disease itself.

The treatment advocated by Lailler is one of the most effective and pleasant, and deserves the praise that Georges Thibièrge has given it. This treatment consists in the giving of a hot bath with soft soap and plenty of friction three times a week in order to remove the epidermal masses, and morning and evening prolonged and light massage of all the affected parts with glycerole of starch made in the following way: ℞ Amyli pulv., 15.00; Glycerini, 150.00. Mix and heat in a porcelain dish over a slow fire, stirring all the time until the mass is about to jelly, when 15 gm. of cherry-laurel water is added.

One can add to this one or two per cent. of salicylic acid, which has the effect of still further softening the skin and aiding desquamation. After a time one inunction a day will be sufficient, and when the skin has assumed its normal appearance Lailler says that one hot bath with soft soap a week, followed immediately with an inunction of the above glycerole of starch, or even of pure glycerin, is enough to maintain a normal suppleness of the skin.

It is important in using the glycerole of starch or pure glycerin that only a moderate amount should be applied so that the skin on finishing is supple and unctuous, but not gluey to the hands. Neutral glycerin only should be used. The advantages of the glycerin treatment are: That the glycerin itself is favorable to maintaining the moistness of the skin through its affinity for water; that even the slightly flat odor that glycerin has can easily be overcome by the odor, say, of cherry-laurel water; that it does not soil the clothing as the greases do, and does not render the clothing difficult to wash; and that it does not become rancid. Instead of using glycerin in the form of glycerole of starch, pure glycerin may be added directly to the bath. About six or eight ounces of glycerin may be added to each bath, and two or three baths a week may be taken.

Instead of adding glycerin to the bath, bicarbonate or biborate of sodium may be added, say one or two tumblerfuls of the powder, to each bath. Vapor baths are enjoyed by some patients, and they are efficacious. Starch poultices with boracic acid added to them, a heaping teaspoonful of boracic acid to a small bowl of starch paste, are an excellent means of loosening up epithelial masses.

Prognosis.—Ichthyosis as a deformity is not dangerous to life. As, however, it represents an extensive developmental fault in an important organ, it indicates a corresponding lack of resistance. As a matter of fact people so afflicted are frequently puny and illy developed in many directions. Usually they have not the normal quantity of subcutaneous fat. They easily become chilled and catch cold, and many of them end with tuberculosis (Lewin). *Douglass W. Montgomery.*

ICHTHYOSIS FŒTALIS.—Definition.—Ichthyosis fœtalis is an independent anomaly of development of the skin in the fœtus, accompanied by consecutive malformation of certain parts of the face. Ichthyosis fœtalis must not be confounded with ichthyosis vulgaris, with which it has nothing whatever to do. It is for this reason that the word ichthyosis in the name of this disease is unfortunate and leads to confusion. Very probably a better name would be hyperkeratosis fœtalis.

The disease is very rare, and even of those children who are born with it, but few come under the observation of men interested in skin diseases, as they usually die shortly after birth, and are therefore seen only by the accoucheur. Only a few of these cases have been reported, and of those few, it has several times occurred that one mother has had more than one child afflicted with this malady, so that ichthyosis fœtalis, like ichthyosis vulgaris, is a family disease. Excepting this fact of its being in many instances a family disease, very little is known of its etiology. Bowen thinks the disease may be due to the persistence of the epitricial layer of epithelial cells. The epitricial layer of epithelial cells occurs in some animals, and Bowen's hypothesis is that it is present at one stage of human fœtal development, but is, under normal conditions, shed. He supposes that in ichthyosis fœtalis it is for some reason not shed, but grows and forms the hard resistant coating seen in these cases.

Symptoms.—The epidermis has a dirty yellow, leathery appearance, and is thickened, and the skin looks too small to contain the infant. In fact it looks as if the infant as a fœtus had been covered by a much thickened and inelastic epidermis, and that in growing it had burst this inelastic coating, forming cracks in it running into one another at all angles. These fissures or cracks are more or less red, and about a centimetre wide, and they may or may not be covered by a thin epidermic layer; when not so covered the raw surface lies exposed, and it soon suppurates abundantly.

In addition to the deformity of the skin there are other deformities present, such as congenital ectropion in which the lids look like red projections hiding the globes of the eyes completely. There are neither eyelashes nor eyebrows, and in fact the whole piliary system is very badly developed. The hair, however, though thin, grows very quickly, as do the nails (Thibièrge). The nose is flat to the face, and is represented by two rounded holes, and the cartilaginous septum is entirely lacking. The lips are thickened and are cut by radiating fissures, or they are entirely absent and the skin of the face may run over directly to the gums. The ear shell is represented by a flattened plateau with a central rounded hole, the external auditory meatus. There are no nipples on the breast, the anus may be imperforate, and the external genital organs are imperfectly developed. The fingers and toes are often bent and clawed, and give the impression of being hidebound. The fingers and toes may be more or less soldered to one another, or they may be entirely absent, the extremities terminating in rounded masses.

The reasons for thinking that the fœtus at one stage of its existence is completely covered with this inextensible horny envelope, which afterward is burst open, are that the direction of the fissures is in all cases about the same, and is such as would be occasioned by the growth of the enclosed fœtus; that the furrows at birth are partially or entirely covered with a thin epidermal layer, which represents the healing process after the bursting has taken place; that the hair follicles are entirely absent from the centre of the furrows, while on the sides the hair follicles are directed outward as would result from tearing the plastic fœtal skin asunder (Peukert); and that the deformities at the orifices of the body, the absence of the eyelids and of the lips, the flattening of the nose and of the ears, as well as the deformities of the hands and feet are such as would be occasioned by the fœtus being hidebound.

Infants with such severe lesions die inevitably, and usually in two or three days after birth. They may not be able to take food at all, because of the malformation of the lips, or they may die from the suppuration in the cracks of the skin, or from bronchitis or pneumonia. Attenuated forms of the disease have been reported, however, in which the patients have lived for years. The mouth seems to be the chief factor in determining the prognosis, as those having a badly formed mouth die of inanition.

Diagnosis.—Ichthyosis fœtalis differs from ichthyosis vulgaris in the time of its appearance, ichthyosis fœtalis being apparent in the fœtus and in the new-born babe, while ichthyosis vulgaris is rarely evident before the second or third year of life. Ichthyosis fœtalis is almost always associated with malformation of the ears, eyes, and lips, and frequently with other malformations. It is rare for ichthyosis vulgaris to be associated with any other malformation whatever. Ichthyosis vulgaris has its regions of greatest development, and it rarely affects the folds of the articulations, but if it does affect them the disease in such situations is very mild. In ichthyosis fœtalis, on the contrary, the disease is as severe in the articular folds as anywhere else. Furthermore, in ichthyosis fœtalis the epidermis is not alone thickened, but it is also abnormally resistant and inextensible. In ichthyosis vulgaris the absence of sweat is a marked characteristic, while in ichthyosis fœtalis the secretion of sweat takes place (Thibièrge). The diagnosis between hereditary syphilis and ichthyosis fœtalis has only to be remembered to be made. Ichthyosis sebacea is simply a temporary exaggeration of the normal physiological desquamation of the new-born, and has nothing whatever to do with ichthyosis fœtalis..

Treatment.—In a case observed by Sherwell, in which the infant lived an unusually long time, it was kept soaked in olive oil. *Douglass W. Montgomery.*

ICTERUS. See *Jaundice.*

IDAHO HOT SPRINGS.—Clear Creek County, Colorado.

Post-Office.—Idaho Hot Springs. Hotel.

Access.—Viâ Colorado Division of the Union Pacific Railroad, the route lying through the famous Clear Creek Canyon. These springs are situated in the Rocky Mountains at an elevation of 7,500 feet above the sea level. The location is exceedingly picturesque, and the climate of a wholesome and salubrious character. Invigorating mountain breezes prevail throughout the summer. The facilities for bathing form a special attraction at these springs. Three immense swimming pools have been constructed, besides numerous private baths, the water ranging in temperature from 85° to 115° F. A natural tunnel furnishes excellent conveniences for a ready-made vapor bath, and is largely resorted to. The following analysis of the Idaho Hot Springs water has been made by J. G. Pohle, analytical chemist:

One United States Gallon Contains:

Solids.	Grains.
Sodium carbonate	30.80
Calcium carbonate	9.52
Magnesium carbonate	2.88
Iron carbonate	4.12
Sodium sulphate	29.36

Solids.	Grains.
Calcium sulphate	3.44
Sodium chloride	4.16
Calcium and magnesium chlorides	Trace.
Sodium silicate	4.00
Magnesium sulphate	18.72
Total solids	107.00

Within five minutes' walk of the Hot Springs there is a cold spring of sparkling, effervescent water, excellent for drinking purposes. A good carriage road leads to the summit of Bellevue Mountain, less than three miles distant, which it is said to afford the most majestic mountain view in Colorado. *James K. Crook.*

IDAN-HA SPRING.—Bannock County, Idaho.

POST-OFFICE.—Soda Springs.

Hotels: Idan-ha, Carriboo, Stock Exchange, and Williams.

The Idan-ha Spring is located two miles from Soda Springs, from whence it is reached by a good roadway. The situation of the spring is 5,886 feet above the sea, and the surrounding mountain scenery is of a grand and impressive character. The climate is very salubrious, the weather being, as a rule, clear and bright. The town of Soda Springs has long been known as a health resort. Within the town limits are the following named springs: the "Horseshoe," "Octonagon," "Williams," "Soda," "Mount" and "Blanche" springs. In the outlying districts are the "Mammoth," "Steamboat," "Hooper," "Jews-harp," and "Fresh-Water" springs. The latter supplies the town with water by a pipe line. Close to the Idan-ha (which is known as the "90-per-cent.") are the "100-per-cent.," the "80-per-cent.," and the "Champagne" springs. An extensive bottling establishment has been built in connection with the Idan-ha Spring, and the waters are shipped and sold in all parts of the country. It is charged with carbonic-acid gas from the Mammoth Spring, two and one-half miles east of Idan-ha, which supplies an immense amount of this substance. The following analysis was made by Prof. Charles F. Chandler:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	13.19
Sodium bromide	Trace.
Lithium bicarbonate	1.27
Sodium bicarbonate	7.34
Magnesium bicarbonate	62.40
Calcium bicarbonate	57.96
Strontium bicarbonate	Trace.
Barium bicarbonate	.08
Manganese bicarbonate	1.73
Iron bicarbonate	.12
Potassium sulphate	1.72
Sodium sulphate	1.96
Sodium phosphate	.68
Sodium biborate	Trace.
Alumina	.05
Silica	3.56
Organic matter	Trace.
Total solids	152.06

This water also contains an excess of free carbonic acid gas. The analysis shows an excellent alkaline-saline water, with ferruginous properties. It should possess valuable properties as a diuretic, mild aperient, and tonic. It is very pleasing to the taste, and possesses the desirable quality of blending with wines and liquors, without giving discoloration or precipitation.

James K. Crook.

IDIOCY AND IMBECILITY. See *Insanity: Idiocy and Imbecility.*

IDIOSYNCRASY.—This term (from ἴδιος, σύν, κρᾶσις, literally, a personal or individual commingling) is applied medically to those mental or constitutional peculiarities of an individual which separate him from the majority of men. To those peculiarities which are shared by *classes* of individuals, on the other hand, the term temperament is given.

One should not include under the term idiosyncrasy qualities due to pathological conditions, as, for instance, the absence of reflexes in tabetic subjects or sensory aberrations like color-blindness, lack of smell or taste perception. But while idiosyncrasies are usually congenital, they may be, as we shall see later in the case of drug and poison addiction, acquired.

The most important idiosyncrasies which fall under the attention of the physician are included under (*a*) sensations, (*b*) reflexes, (*c*) infections, (*d*) foods, (*e*) drugs and poisons.

(*a*) *Sensations.*—One of the most marked idiosyncrasies has to do with response of a given individual to pain. This is shown, for a common illustration, in the matter of vaccination. The actual insult to terminal sensory nerves in a series of patients submitting to this little operation is about the same; but while some of them will notice no hurt whatever, others will shrink and cry out in evident acute pain. Some few will faint. This varying personal factor of pain susceptibility must receive due consideration by the physician in interpreting the symptoms which a patient describes. Other minor discomforts, which yet from a nosological standpoint may be important, receive very varying attention from different people. For example, the writer has observed a large scrotal tumor in an elderly bookworm who said, on his attention being called to it, that he had never noticed its presence at all. Or, again, a woman is found with a completely procident uterus to which she had never given any thought; whereas most women with a far less pronounced degree of prolapsus would have early sought medical advice.

Auditory sensations have a peculiarly unwelcome effect on certain people. The squeak of a file, of a saw, or of a slate pencil are familiar examples. Shylock emphasizes these sensory idiosyncrasies when he says:

> "As there is no firm reason to be rendered
> Why he cannot abide a gaping pig,
> Why he, a harmless, necessary cat,
> Why he, a swollen bag-pipe . . .
> So can I give no reason, nor I will not
> More than a lodged hate and a certain loathing."

(*b*) *Reflexes.*—These are perhaps more important medically than the class just considered.

Sea-sickness deserves first mention here, from its wide prevalence. In fact it is perhaps the absence of this reflex susceptibility that constitutes the idiosyncrasy. Certainly there is no way of foretelling which individuals will prove able to resist it. Freedom from it is to some extent cultivable, though it is well known that some sea captains and naval officers even lose what they have gained in that direction after a short residence ashore.

Hay fever doubtless belongs in this category, for while a pathological lesion exists in a certain proportion of cases, a reflex idiosyncrasy to certain irritants is also a factor. Whatever this irritant may be, it is doubtless similar in its action to ipecac upon another sort of idiosyncrasy. The writer knows a druggist who is so susceptible to the reflex irritation of this drug that he not only cannot dispense it himself, but is obliged to leave his store when any of his assistants is doing so.

Asthma probably owes a part at least of its etiology to a similar reflex idiosyncrasy. For while we have a determining cause in some pathologic state of the respiratory tract, and an exciting cause in an acute inflammation of the bronchi, or elsewhere, we must assume in asthmatics a predisposing cause in a peculiar reflex irritability; for not all persons possessing the first two conditions have asthma.

Another reflex idiosyncrasy is that which enables the rigger and the steeple-climber to ascend to high places without giddiness or fear of falling.

It is a failure of natural reflex response to cold baths and cold affusions which explains the idiosyncrasy noted in some people at water-cure establishments. On the other hand, those untoward results of baths which include skin eruptions, eczema, furunculosis, etc., are, in so far as they are not due to uncleanly methods, to be classed in the following section among therapeutic idiosyncrasies.

(*c*) *Infections.*—The present article does not touch upon the subject of *Immunity* (which see). But there is in some persons a lack of susceptibility to various diseases which can be ascribed only to idiosyncrasy. This is well illustrated by vaccinia, there being a very few persons upon whom vaccination cannot be made to "take" no matter how often repeated. Some families of children escape in epidemics of the exanthemata, while others have these diseases several times, seeming to be unable to acquire the usual immunity from one attack. The universal exposure to the bacillus tuberculosis would indicate that the varying resistance of different individuals was largely a matter of idiosyncrasy.

(*d*) *Foods.*—There are many instances of idiosyncrasy as regards special articles of diet. One person, for instance, not only cannot eat cheese without violent gastro-intestinal irritation but cannot eat comfortably at a table where it is served. A special form in which these food idiosyncrasies assert themselves is in the production of urticaria from the use of them. Familiar examples are fish and shell-fish, especially lobsters; also strawberries and peaches. The latter fruit with some patients will cause an intense coryza apparently like a rose-cold. Herpes and angioneurotic œdema are similarly produced. Milk is an article of diet which many persons, generally mistakenly, think they cannot take. But there are really some who undoubtedly do have an idiosyncrasy against it. Regarding this as every other article of diet, a person should, often with medical supervision to guard against error, establish the fact of his own idiosyncrasy, and having once established it should thereafter respect it.

(*e*) *Drugs and Poisons.*—In this field idiosyncrasy may show itself either by an unusual susceptibility to a small dose, or, on the other hand, by a lack of susceptibility to the average physiological or even toxic dose. The former of these conditions is usually congenital; the latter may be either congenital or acquired. To it is given the technical name of "tolerance.".

A high degree of tolerance is usually an acquired condition. It is well known that in both man and the lower animals, increasing doses of a toxin can be given till doses are tolerated far in excess of what would be fatal without such a progressive increase in dosage. The use of the toxin of diphtheria in the preparation of antitoxin is a familiar example of this. The same tolerance is established in the case of non-bacterial poisons, as, for example, tobacco, alcohol, and arsenic. But while such tolerance may appear to be present in certain organs or systems of the body, it may be absent in others. For example, the nervous system may appear to be resisting tobacco or alcohol, while the cardiac or digestive may be in reality succumbing to its use, or vice versa.

Such an acquired tolerance, whether in the case of toxins or of drugs, ceases soon after the regular administration of the poison has been stopped. The term Mithridatism was applied to a supposed immunity against poison gained by King Mithridates through the systematic use of poisons employed for that end.

The Styrian peasants have long been noted for their acquired tolerance for arsenic. One sceptical traveller is recorded to have administered seven grains of arsenious acid to an apparently healthy Styrian without ill effect. The enormous doses of morphine taken by morphinomaniacs of course suggest themselves in this connection.

A tolerance for one drug sometimes develops a tolerance for others of similar nature. To this may perhaps be ascribed the large amount of ether required to anæsthetize a habitual alcoholic. The writer once saw a morphine habitué who after taking nearly a drachm of morphine with suicidal purpose added to the dose over one hundred grains of chloral, to which he was not specially addicted, but the conjoined dose had no serious effect. Insensibility to large doses of sedatives, as ether, chloroform, opium, hashish, and bromides, is found in some persons not habitués of any of these drugs. Such persons are apt to be of a hysterical or emotional character. A lack of response to large doses of cathartics may be dependent on the cathartic habit or may be met with independently of it. People of warm climates are said to require exceptionally large cathartic doses.

Many persons are aware of their own drug idiosyncrasies, and may properly acquaint a strange physician with them. It is unwise to disregard such information if given by a person of intelligence. In doing so one is liable to repeat the disastrous experience of a previous attendant, and even if the experiment has no other ill-effect than the temporary discomfort of the patient, the latter is likely to feel provoked that his warning was not regarded. But of course the patient may have drug idiosyncrasies which are unknown to him. It is therefore unwise for a physician in case of untoward symptoms arising, to say offhand that they could not possibly be due to the use of a given drug, even though in his experience such a result had never occurred.

It may be said in passing that sometimes a pathological condition of some organ, involving too slow or too rapid absorption or impaired elimination, is at the bottom of what is regarded as a congenital drug idiosyncrasy. Thus renal inadequacy has been found in some persons who could not take iodine.

Childhood appears to present some special features with regard to drug susceptibility. Especially opium should be used very cautiously at this period. There is a common belief, on the other hand, that arsenic and belladonna are especially well borne by children. I think it very doubtful if this be true of the latter. Jacobi thinks children tolerate relatively large doses of quinine, digitalis, potassium iodide, and mercury.

It remains to mention a few specific drugs and poisons in regard to which marked individual idiosyncrasy is most often met.

Ivy Poison. Here all degrees of susceptibility are met, from perfect immunity to the most intense dermatitis following the slightest contact.

Alcohol. Here we find not only quantitative but qualitative idiosyncrasies One man can drink down all his fellows, while the others with an equal quantity of liquor may show either amativeness, quarrelsomeness, hilarity, or gloom.

Quinine is a drug which occasionally produces ill effects in a dose much smaller than ordinarily given. Such effects are tinnitus, deafness, blindness, and erythema. The writer has seen an intense universal dermatitis follow its use, and has known a clergyman in whom a dose of two grains invariably produced a marked erythema of the scrotum. Fever and abortion have both been reported to follow the use of quinine.

Salicylic acid will cause at times an intense delirium. I have seen it simulate an acute mania and last nearly a fortnight.

Belladonna also, as is well known, causes delirium in certain patients. *Opium* has caused vomiting, wakefulness, convulsions, and delirium. Doubtless there are some persons who should never take the drug. In the first use of the hypodermic syringe upon strangers a considerable conservatism is wise.

Potassium Iodide. Perhaps no drug reveals more of personal idiosyncrasy than this. Two to five grains often cause coryza. Four ten-grain doses have produced an œdema of the glottis severe enough to require tracheotomy. Fifteen grains a day will often cause a good deal of acne. But, curiously, patients who cannot take the small doses often can take the large one, and the massive doses of four to six drachms three times a day are generally well borne. One cannot insist too firmly that the tolerance for this drug is *not* a diagnostic criterion of syphilis. *Charles F. Withington.*

IGAZOL is said to be a mixture of formaldehyde, paraformaldehyde, and an iodine compound of unstated nature. It is in the form of a powder and was introduced by Cervello as a remedy for tuberculosis. Norway used it by vaporizing over a lamp for two hours three times a day. He reports good results in asthma, laryngeal spasm, and phthisis. It has no specific action.

W. A. Bastedo.

IGNATIA.—Saint Ignatius' Bean. The seed of *Strychnos Ignatii* Berg. (fam. *Loganiaceæ*). This is a large, half-climbing shrub, with very long, slender branches, and rather large, oval, pointed, three-nerved leaves. The flowers resemble those of *S. Nux vomica,* and the fruit is a very large (10 to 20 cm.), solid, many-seeded, hard berry. The plant grows in the Philippine Islands, and has been introduced into Cochin-China. The fruit appears to be not uncommon in some Asiatic markets. The seed has been known to Europeans since 1699 (Flückiger).

Saint Ignatius' Beans are hard, oblong, but irregularly faceted seeds, 2 or 3 cm. in length, of a dull yellowish-gray or blackish color, and corneous texture; they are normally covered with short, coarse, appressed, glistening hairs, but these are usually rubbed off before they reach this country, probably by the friction of the long voyage or carriage. The seed consists mostly of perisperm, but contains an oblong embryo, 6 or 8 mm. in length, in a cavity near the centre. The seeds have but little odor, and a very bitter taste.

Composition.—*Strychnine,* to the extent of from one to one and a half per cent.; *brucine* from one-half to three-fourths per cent.; considerable albuminoid matters; no starch. These seeds, from chemical, structural, and physiological points of view, are qualitatively so exactly duplicates of nux vomica that the reader is referred to that article for further information. Because it was supposed to be more uniform in its alkaloidal percentage, and in the relative percentages of strychnine and brucine, this drug was made official in 1880, but it was found impossible to induce physicians to substitute it for the familiar nux vomica, and it was dropped at the 1890 revision. An abstract, of fifty-per-cent. strength, dose 0.06 to 0.3 gm. (gr. i.–v.), and a tincture of the same strength and dose as that of nux vomica, were supplied.

W. P. Bolles.

IMMUNITY.—The past few years have added a great deal to our knowledge concerning the nature of immunity, but there is still much to be learned. Care must therefore be taken, while discussing the many plausible theories advanced, to remember always that they are but theories and may be, however interesting, still untrue.

Experience and observation have taught us that various races of animals and men, and various individuals among these, differ in their susceptibility to certain diseases; and, further, that the same individual is at one time more resistant to such diseases than at another. This inborn or spontaneous refractory condition is termed natural immunity, in contradistinction to that acquired during an attack of disease.

As in bacteria we distinguish between the ability to produce poison and the power to multiply, so in animals and man we may distinguish between immunity to poison and immunity to the invasion of bacteria.

With regard to variations in susceptibility, certain facts have been ascertained. Thus, cold-blooded animals are generally insusceptible to infection from those bacteria which produce disease in warm-blooded animals, and *vice versa.* This is explained in a measure by the inability of the bacteria which grow at the temperature of warm-blooded animals to thrive at the temperature existing in cold-blooded animals. But differences are observed not only between warm-blooded and cold-blooded animals, but also between the several races of warm-blooded animals. The anthrax bacillus is very infectious for the mouse and guinea-pig, while the rat is not susceptible to it unless its body resistance is reduced by disease and the amount of infection is great. The inability of a micro-organism to grow in the body of an animal does not necessarily indicate, however, an insusceptibility to its poison; thus, for instance, rabbits are said to be less susceptible than dogs to the effects of the poison elaborated by pneumococci, but these bacteria develop much better in the former than in the latter. Differences in susceptibility are sometimes very marked among different varieties of the same race of animals, as, for instance, between different kinds of rats and pigeons to anthrax. In animals, as a whole, experiments have shown that the young of all species are on the average less resistant to infection than the older and larger ones.

The difficulty experienced by many micro-organisms in developing in the tissues of the healthy body can be to a great extent removed by any cause which lowers the general or local vitality of the tissues. Among the causes which bring about such lessened resistance of the body are hunger and starvation, bad hygienic surroundings, exhaustion from overexertion, exposure to cold, the deleterious effects of poisons, bacterial or other, acute and chronic diseases, vicious habits, drunkenness, etc. Purely local injuries, such as wounds, contusions, etc., give a point of entrance for infection, and also through tissue injury one of less resistance, where the bacteria may develop and produce local inflammation. Local disease processes, such as endocarditis, may also afford a weak spot for the bacteria to seize upon. The presence of foreign bodies in the tissues in like manner predisposes them to bacterial invasion. Interference with free circulation of blood and retention in the body of substances which should be eliminated also tend to lessen the vitality. In these and other similar ways animals which are otherwise refractory may acquire a susceptibility to bacterial invasion.

Just as all conditions which are deleterious to the body lessen its power of resistance to bacterial invasion, so all conditions which are favorable to it increase its resistance, and thus aid in preventing and overcoming infection. The internal use of antiseptics against bacteria has not proved successful, for the reason that of all known non-specific bactericidal substances an amount sufficient to inhibit bacterial growth is found to be poisonous to the tissue cells. The efficacy of quinine in malaria and of mercury in syphilis is, possibly, an exception to the rule, but in both cases we are dealing probably with animal parasites, not bacteria. Such substances as nuclein and others contained in blood serum, when introduced into the body in considerable quantity, aid somewhat in inhibiting the growth of many bacteria. Even bouillon, salt solution, and small amounts of urine have a slight inhibitory action. The hastening of elimination of the bacterial poisons by free intestinal evacuation and encouragement of the functions of the skin and kidneys are also of some avail. The enzymes formed by certain bacteria have been found to exert a slight bactericidal action, not only on the germs which have directly or indirectly produced them in the body, but also on other varieties. None of these enzymes is sufficiently protective, however, to be of practical value nor equal in power to the protective substances formed in the body after infection with many micro-organisms.

The tissues of the animal body under the normal conditions of life are unsuitable for the growth of the great majority of bacteria, and are only fairly favorable to the development of the few remaining. Indeed, only a very small number of varieties of bacteria find the conditions really satisfactory, and even these must gain a point of entrance.

In seeking for a reason for the difficulty experienced by the bacteria in growing in the tissues, we cannot expect to find it in either the lack of or concentration of the nutritive substances, in the temperature, or in the reaction; for although these conditions may be unsuitable for some bacteria they are suitable for many, and thus cannot constitute the fundamental explanation of immunity. A possible reason for the inability of the bacteria to invade living tissues may be in the fact that the nutritious material in the living cells is in a form which the bacteria cannot readily assimilate; but if this be true it does not adequately explain why the bacteria do not develop in the nutritious fluids so abundant about and in the body tissues. We are thus driven to the conclusion that the body fluids themselves contain substances which are directly deleterious to the bacteria. As to the origin of these substances, it is conceivable that they may be either regularly produced in the cells or that they may be produced only when the body is invaded by micro-organisms. They may then remain unaltered in the fluids or be quickly eliminated. More than one of these things may actually occur.

The bactericidal effect of sera upon most bacteria is shown by the fact that when injected into the blood they begin to die at once, and this often continues until in a few hours all have died. Even when bacteria produce infection there is usually for a time a decrease in the number of bacteria living, but this is soon followed by a progressive increase. This fact can be observed not only in the blood and peritoneal cavity, but also when the bacteria are enclosed in animal or vegetable capsules, where the serum passing into them destroys the bacteria. The bacteria are killed even if they have previously grown in blood serum. Bacteria have also been injected into a vein carefully ligated above and below, and here without coagulation the blood exerts bactericidal properties. Even spores are killed in a few days. The effect of the fresh unheated blood serum can also be watched outside of the body. Here some species of bacteria die quickly, some slowly, and some lose only a portion of their number, and here the remaining portion after a time rapidly increases. The number of bacteria introduced is of great importance, for the serum seems capable of destroying only a certain number and after that loses its bactericidal properties.

If the bactericidal effect of the serum outside the body always went hand-in-hand with the immunity of the individual from which it was taken, the problem of immunity would be more easily solved, but this is not wholly the case. We must therefore add to the serum the activity of the cells which constantly produce the antiseptic substances which are given up largely to the blood and fluids of the body. This deleterious action of the blood on bacteria can be increased or diminished by infection, thus indicating living-cell influence.

Concerning the nature of these protective substances, named *alexins* by Buchner, we have as yet little positive knowledge, but certain properties of them are known. They are precipitated by a forty-per-cent. solution of sodium sulphate. A bactericidal serum affects in a deleterious manner the red blood cells of a different species of animals. These substances would seem to belong to the proteids and resemble certain of the globulins in their properties, but they are evidently extremely complex in their nature.

Their source is generally attributed to the cells, but probably certain cells only produce them. The red blood cells, for instance, seem rather to destroy than to increase them. The nuclein derived from the cells, although it has a general bactericidal action, does not belong to the specific alexins. The cells which have abundant nuclear substance, such as the leucocytes and lymph cells, seem especially to be a source of the alexins. Buchner and others have found that, through the irritation of bacterial filtrates, the leucocytes were attracted in great numbers to the region of injection, and that the fluid here, which was rich in leucocytes, was more bactericidal than the blood serum elsewhere. The same fluid acted also more perfectly when it contained numbers of leucocytes than when they were filtered out. Substances similar to the alexins are apparently derived from the leucocytes and their attraction to the injected areas gives to that location greater protective power. Still it has not yet been positively established that the specific alexins are derived from the leucocytes. The attraction between the leucocytes and the bacteria is rather due to the chemical attraction of the bacterial cell products and the bacterial body substance. Some chemical substances not derived from bacteria have also this quality, called positive chemotaxis, while others repel the leucocytes—negative chemotaxis. The theory of Metchnikoff that the leucocytes are the only actual protective bodies which ward off disease, and that they do this by attacking and devouring the bacteria, has been somewhat modified by more recent knowledge, and it is now believed that the bacterial substances attract the cells and that when these are brought together the general, and perhaps the specific, bactericidal property of the blood is thereby increased. The death of the bacteria liberates this positive chemotactic substance, and the death of the leucocytes gives rise to an increase of the non-specific bactericidal bodies. Thus we find that phagocytosis is most marked when the disease is on the decline or the infection mild, but that in rapidly increasing progressive infection it is usually absent. This would seem to indicate that the course of the infection is already determined before the leucocytes become massed at the point of its entrance. The first determining influence is given by the condition of the tissues and the bactericidal substances contained in them, and then later, in cases in which the infection is checked, comes the additional bactericidal substance given off by the attracted leucocytes. In so far as the tissues themselves are unsuitable for the development of bacteria they are sufficient to ward off infection, but in proportion as they are incapable of doing this they are assisted by the substances contained in the leucocytes. If the tissues are wholly adapted for the growth of the bacteria, neither they nor the leucocytes, nor both combined, can furnish sufficient protective substances to prevent the bacterial increase. The entrance of bacteria into the leucocytes, which is not infrequent, may mean the destruction of the former, but, on the other hand, the bacteria may increase in the white blood cells and destroy them, and they may be killed without entering the cells. The simple absorption by the cells is not necessarily a destructive process.

No explanation can as yet be given of natural immunity to bacterial poisons, except that it may be connected with some general property of the protoplasm of the cells which renders a combination between certain molecules of the cell and the poison impossible; thus, if tetanus toxin is injected into a susceptible animal it has been found that it will disappear from the blood in a few minutes. If the cells are subjected to suitable processes the tetanus poison will be found present in all the cells except those of the nervous system. In these it has apparently disappeared. As these are the cells that received injury from the toxin it is fair to assume that some chemical combination has occurred between them and the toxin. There is far less variation among different species in their resistance to the bacterial poisons than in their suitability for the growth of the living bacteria which produce them. Possibly certain organs, such as the lymph glands, the liver, etc.—may have some destructive power with regard to poisons.

By what means are virulent bacteria enabled to increase in the body, notwithstanding its protective powers, when non-virulent organisms of the same species are incapable of so doing? This is but little understood, but experiment shows in the first place that both virulent and non-virulent forms are equally resistant to general destructive agencies; and, secondly, that the bacteria are capable of producing substances (*lysins*) which neutralize in some way the protective substances (alexins). The virulence of bacteria would, therefore, depend partly upon their ability to produce these lysins, which act perhaps as the ferments upon the alexins, or perhaps combine with them. That bacteria under certain conditions form specific poisons, and under others, even when they grow luxuriantly, do not, is clearly shown by our experiments on the production of diphtheria toxin. Here it was found that when the bouillon was either a little too alkaline or too acid, though the bacilli grew rapidly, they did not produce specific toxins. When the bacilli were grown for a time in such bouillon they eventually became able to develop toxin in a soil in which they previously failed to do so. Similar cultivation in the body may be assumed to increase their ability to produce specific poison after a while under what would at first be adverse conditions.

With regard to the increase and decrease of general, and perhaps also of specific immunity, we have reason to believe that as the protective substances are produced through the action of the living cells, anything which lowers the general vitality must lessen the vitality of the cells, and thus their ability to produce protective substances in the amount possible in a normal condition.

Specific Immunity.—The following theories have been advanced concerning the nature of specific immunity: The theory that a second infection is impossible because the first used up substances which were necessary to the growth of the bacteria is untenable for many reasons. Thus it can be demonstrated that the injection of a small amount of specific serum, which robs the tissues of nothing, produces the same immunity. Again, the injection into the body of a sufficient number of bacteria pathogenic for the animal selected gives rise to an infection in all cases.

The original theory of Metchnikoff, that the leucocytes or wandering cells of the body, after an infection with a certain variety of bacteria, become influenced in some way, so that they attack especially that form of infection again and destroy the bacteria (phagocytosis), can no longer be regarded as more than a very partial explanation, and can be accepted only by assuming as proven a number of hypotheses.

The retention theory of Wernich and Chaveau, somewhat modified, has most to support it. They have shown that the chemical changes in the blood serum of animals recovering from an infection are of such an extent as to be capable of being demonstrated experimentally, and these changes have been shown to persist for a number of weeks or months or even years. Similarly the serum of immunized animals retains for a long time its immunizing substances. We are therefore compelled to accept the fact that when an infection is passed through there are more or less protective chemical substances left in the blood which remain there for a considerable time. Kruse believes that these substances have the power of neutralizing the poisons which are given off by the bacteria upon their entrance into the body, and of thus robbing these poisons of their deleterious effects on the alexins; the body fluids in this way remaining antagonists to the growth of the bacteria, the alexins being bactericidal. If only a small amount of antilysins are present some of the alexins are destroyed and the bacteria are not all killed or weakened. Those remaining active are then further acted upon by the alexins in the tissues and by the substances given off by the leucocytes. If these protective substances are insufficient the infection is established.

According to Ehrlich the production of antitoxins and of the specific portion of bactericidal sera is due to overproduction of molecules in cells sensitive to the toxins or bacterial cell products. Ehrlich considers that toxin molecules have what he calls haptophore atom groups which find in sensitive animals cells and atom groups having for them an affinity. The groups unite and later the poison or toxophore atom group of the toxin molecule having been assimilated acts upon the vital part of the protoplasm of the cell, and injury results. This injured cell substance is replaced by the cell in excess, and this excess is thrown off free in the blood. This free cell substance has affinities similar to what it had in the cells and so unites with the toxin molecules, and satisfying them, neutralizes their poisonous properties.

When the substance of bacterial cells is injected into a susceptible animal body, there results in the same way as with toxins an injury of certain cell molecules, and an attempt at repair, with usually an overproduction. The specific substances produced cannot alone attack living bacterial cells similar to those whose protoplasm has previously caused the injury. To destroy the bacterial cell, besides the specific "antibody" there is needed a complementary body. This is the substance normally present in all healthy sera. The two substances together, uniting with the bacterial cell, destroy it.

According to Ehrlich these specific substances are present in minute amount in all living animals. After an injection or a series of injections, that one which has affinity for the poison or bacterial protoplasm is enormously increased. These atom groups of the large molecules of certain body cells are "side chains" as it were, which stand in the same relation as the side chains of the aromatic attachment to the benzol nucleus. On the ability of these groups to unite lies their tendency to be poisoned or to protect.

The agglutins seem to have a close resemblance to, if they are not identical with, the antibodies, which together with the complementary bodies destroy the bacteri

Ehrlich's "side-chain" theories are most interesting; whether they have in them a foundation of truth, or not, only further investigation can reveal. They have, however, helped greatly to establish that the protection given by antitoxic and bactericidal serums is due, for the most part at least, to purely chemical action, the antitoxins uniting with the toxins, and the bactericidal antibodies and complementary bodies combining with the bacterial cells.

An important fact recently established is that while we may accumulate antitoxin to almost any extent in the blood of infected animals, we cannot so increase the bactericidal substances in the serum, for the complementary body which is essential can never be increased in the blood much beyond the extent to which it is normally present in the blood. We can neutralize any amount of toxin by sufficient antitoxin, but we cannot protect an animal from death from a septicæmic germ, if we give an excessive quantity of bacteria. At the present time, therefore, we cannot be hopeful of having protective sera which will be of much value in the treatment of disease, when an extensive invasion of the body by bacteria has taken place.

With antitoxins we seem limited also to those cases in which we can give the antitoxin before sufficient toxin has united with the body cells to produce fatal injury. If even seven minutes have elapsed after an excessive amount of tetanus poison has been injected into a sensitive animal, no amount of antitoxin will protect it from death, while if previous to the injection of the toxin, the same amount of antitoxin has been mixed with it, no harm results.

The injection of toxins and bacterial poisons is followed after forty-eight to ninety-six hours by the development of protective substances. The immunity reaches its height a week or ten days after the injection, and then continues for a week or two, when it slowly declines again. When protective sera are injected the immunity is greatest at the time of the injection and then gradually lessens. The immunity following serum injections is frequently called passive immunity and that due to bacterial or toxin injections active immunity.

If a greater quantity of protective substance is desired in the blood than occurs after one infection, repeated injections of living or dead bacteria or their products are given, the doses being administered at short intervals and in sufficient amount to produce a slight elevation of temperature and malaise. Then, as soon as the animal returns to a normal condition, another injection of slightly greater quantity is given. After several months of such treatment the blood is withdrawn, allowed to clot, and the serum then siphoned off aseptically and stored either with or without the addition of preservatives. The serum is tested by mixing it with a certain number of times the fatal dose of a culture or its toxins whose virulence or toxicity is known, and then injecting this under the skin, in the vein, or into the peritoneum, according to the nature of the bacteria to be tested. The main point is that some definite method be carried out by which the relative value of the serum can be judged in comparison with other serums. As a rule, the value is stated in the number of fatal doses of culture or of toxin which a fraction of a cubic centimetre of serum will prevent from destroying the animal. It is well to remember that with a living germ a multiple of a fatal dose is not as much more severe than a single dose as the figure would suggest. One thousand times a fatal dose of a very virulent micro-organism will be neutralized by several times the amount of serum which a single fatal dose requires, since in the case of very virulent living bacteria whose virulence is due to their ability to increase, it is not the organisms which are introduced that kill but the millions that develop from them. As a rule, the serum has to be given before the bacteria introduced into the body have multiplied greatly. After that period has elapsed the serum usually fails to act. The immunity conferred on a person from serum lasts from a few days to several months, according to the amount of serum injected. As in animals, it is strongest immediately after absorption. An injection of bacterial poisons or the contraction of actual disease usually confers immunity in from one to three weeks after the infection, which lasts, according to the nature of the infection, from one month to a year or more. The serum loses all appreciable protective value as measured in test animals in the usual doses before the person is liable to infection. Repeated injections of serum continue this condition of immunity indefinitely.

The use of sera having specific protective properties has been tried in both animals and man as a preventive of infection. In susceptible animals injections of some of the very virulent bacteria, as pneumococci, streptococci, typhoid bacilli, and cholera spirilla, can be robbed of all danger if small doses of their respective sera are given before the bacteria have increased to any great extent in the body. If given later they are ineffective. For some bacteria, such as tubercle bacilli, no serum has been obtained of sufficient power to prevent infection. Through sera, therefore, we can immunize against an infection, and even stop one just commencing; but as yet we cannot cure an infection which is already fully developed, though even here there is reason to believe that we may possibly prevent an invasion of the general system from a diseased organ as by the pneumococcus from an infected lung in pneumonia. On the whole, the sera which simply inhibit the growth of bacteria have not given, as observed in practice, conclusive evidence of great value in already developed disease. This is partly due to the difficulty of determining early enough the exact nature of the bacteria causing the infection. Although the serum of animals which have been infected with any one of many varieties of bacteria is usually both antitoxic and bactericidal, still one of these protective substances may be present almost alone; thus antitoxic substances are present almost exclusively in animals injected with two species of bacteria which produce powerful specific poisons—the bacilli, namely, of diphtheria and of tetanus. When the toxins of either of these are injected in small amounts the animals after complete recovery are able to bear a larger dose without deleterious effects, and these doses in the more suitable animals can be gradually increased until a thousand times a previously fatal dose may be administered without any serious results whatever. To Behring and Kitasato we owe the discovery that this protecting substance accumulates to such an extent in the blood that very small amounts of serum are sufficient to protect other animals from the effects of the toxin.

Some other important parasitic bacteria produce toxins and in the body antitoxins, but all to a far less extent than those of tetanus and diphtheria. Following them is the plague bacillus, and then, but far behind, the cholera spirilla, the typhoid bacilli, the streptococci, etc. These latter bacteria produce more of the substances which inhibit bacterial growth than of those which neutralize their toxins.

Inherited Immunity.—Natural immunity pertains more to species than individuals, and such immunity is handed down by the parents to their offspring. If the immunity of one or both parents has been acquired by them during their lifetime previous to the birth of the offspring the immunity conferred is slight or none at all. This is especially true of the male side. In the case of the female parent another factor comes into play after the fructification of the ovum,—viz., the absorption of products from the fluids of the mother, for the placenta is no barrier to soluble substances. Thus, sheep which have been immunized to anthrax have moderately immune young. On the other hand, animals vaccinated with cowpox have not been found to have immune offspring. Antitoxins injected into the parents apparently pass the placenta, giving thus a slight transitory passive immunity. A slight immunity is also given by immune mothers through their milk, a small amount of antitoxic substance being absorbed. *William H. Park.*

IMPETIGO.—This is an acute specific inflammatory affection of the skin, spontaneously and experimentally inoculable, contagious, and epidemic; characterized by the formation of superficial flaccid vesicles which soon rupture and give place to crusts formed by the drying of the effused serum. These crusts are without inflammatory areola and look as if stuck on the sound skin, the underlying epidermic erosions healing in a few days without leaving cicatrices.

Impetigo is a disease peculiar to infants and young children, not that there is with them any special underlying predisposing cause in the soil, so to speak, such as a strumous or lymphatic condition as is often alleged, but that simply their skins are more delicate, particularly that of the face, where the corneal epidermis is less thick and where impetigo occurs most frequently.

Given an erosion of the skin—and the thinner the skin the more easily does erosion occur—and the introduction of the special germ, a characteristic lesion of impetigo will result. The *accidental* causes which lead to this inoculation are those that conduce to scratching by which the skin is broken, such as phthiriasis, especially of the scalp, and scabies. Eczema may lead to impetigo. The contagiousness of impetigo was clinically established by Devergie and experimentally proven later by Tilbury Fox, of London, and others. Fox prefixed the term contagious, which would make it appear that his "contagious impetigo" was a different affection from the impetigo of the French school, which is not the case. Impetigo and "contagious impetigo" are one and the same disease and "contagious" is an entirely unnecessary and confusing qualification. Through the more or less intimate association with the greater opportunity for contagion that takes place in schools and families, impetigo may become epidemic solely through the inoculation of one by the other of the members of such bodies. The direct and efficient cause of impetigo is a microorganism—one of the streptococci.

The elementary lesion of impetigo is an erythematous spot but slightly if at all elevated, varying in size from the head of a large pin to that of a split pea. This lesion is very transitory and gives place in a few hours to a superficial flaccid vesicle containing a clear limpid serum. The thin corneal covering of this blister-like lesion is easily ruptured, spontaneously or by scratching, allowing to exude a limpid serum which quickly coagulates and forms the characteristic honey-like crusts that appear as if stuck on the sound skin. An accumulation of these friable amber-yellow crusts, without surrounding inflammatory areola, over the cheeks, forehead, and chin, and around the lips, presents a classical picture of the disease known as impetigo. It may occur on any part of the body, but the face is the familiar location. At times, after the breaking of the imperfect vesicle, little or no exudation will take place, so that no crusts are formed, there being merely a thin glaze over the underlying superficial erosion which heals quickly, leaving an erythematous spot that slowly disappears. This abortive attempt is noticed more frequently in grown persons. Ordinarily through successive reinoculations an attack of impetigo will last for from three to four weeks. The burning and itching, though slight, are sufficient in a child to cause it to scratch the lesions, thereby infecting the finger nails, and thus transference to other parts is effected with the establishment of new lesions. When uncomplicated, the lesion of impetigo never suppurates and terminates, after falling of the crust and the gradual disappearance of the underlying reddened, area without cicatrix.

Impetigo may be diagnosed from varicella by the more widespread distribution of the latter, impetigo being essentially regional; the vesicle of varicella is smaller and more prominent, is surrounded by a wide area of erythema, and dries up into smaller and far less bulky crusts.

From ecthyma the diagnosis is made by the distribution of the lesions of the latter on the covered portions of the body, and by the greater intensity of the inflammatory process in ecthyma with accompanying indurated base, wide inflamed areola around the crust-covered pustule, and deeper erosive action upon the skin.

A bullous impetigo—a rare form—has at times been erroneously reported as "acute pemphigus in children."

A crusted impetigo lesion may simulate a syphilide, especially when situated around the mouth and chin in adults; if the lesion is one of syphilis the crust on being removed will be found to have surmounted a papule or a sanious ulcer.

Treatment is simple and effective. Removal of the crusts by soaking in olive oil until they are easily detached is the first step, after which an application, renewed twice daily, of a five- to ten-per-cent. ointment of ammoniated mercury will complete the healing in a few days, leaving only the after-redness which in turn gradually disappears. This treatment is all-sufficient, and while there are many other remedies that will perhaps cure as well, there is none better than this.

Charles Townshend Dade.

IMPOTENCE. See *Sexual Organs, Male, Affections of.*

IMPREGNATION is the union of two germ cells, to form a single new cell, capable of initiating by its own division a rapid succession of generations of descendent cells. This process is more frequently called *fertilization* or *fecundation.* The new cell is called the impregnated, or fertilized, ovum; also, especially in botany, it is called *oöspore* or *zygote.* The production of cells from it is called its segmentation, or cleavage. For the theory of the relation of the elements to one another and to other cells, see *Sex;* for accounts of the sexual bodies, see *Ovum* and *Spermatozoon.*

In all multicellular animals, impregnation is effected by three successive steps: 1, The bringing together of the egg and spermatozoon; 2, the entrance of the spermatozoon into the ovum, and formation of the sperm nucleus; 3, fusion of the sperm nucleus with that of the egg to form the segmentation nucleus. We proceed to consider these steps in their order.

1. The Bringing Together of the Germ Cells.—This is effected among animals in a great variety of ways, which, however, fall into two groups, according as the impregnation is effected, (*a*) outside the body of the mother, or (*b*) inside. The simplest manner is the discharge of the eggs and spermatozoa at the same time into the water, leaving their actual contact to chance, the method of the osseous fishes for the most part, and of many invertebrates. An advance is the copulation of the Anura (frogs, etc.), the male embraces the female, and as the latter discharges the ova, ejects the sperm upon them. In the higher vertebrates the seminal fluid is transferred from the male to the female passages during coitus. The physiology of this complicated function does not fall within the scope of this article.

For a long time it was not known how the semen fertilized the ova; the problem was long fruitful of fruitless speculation. The first step toward gaining actual knowledge was the discovery of the possibility of artificial fecundation by Jacobi, in 1764. Spallanzani was the first to take advantage of this, and to show that fecundation implied a material contact of the semen with the ova, and thus to set aside De Graaf's notion of the *aura seminalis.* But not until fifty years later did the memorable experiments of Prévost and Dumas (*Annales des Sciences Naturelles,* 1824) establish the fact that the spermatozoa are the essential factors of fertilization. Again, a little over fifty years later, Hertwig and Fol showed that one spermatozoon suffices to impregnate an ovum.

We have then to consider how the spermatozoa, after the semen has been transferred to the female, attain the ovum. They are found in mammals after copulation in the vagina and even in the uterus, but it is not clearly ascertained how they get beyond the vagina. It is probable that they travel through the female passages partly by the movements thereof, partly by their own locomotion, and enter the Fallopian tubes, though why or how is really unknown, and pass upward to meet the ovum. They are found in considerable numbers in the Fallopian tubes. The ovum meanwhile travels down the oviduct, it probably being impelled by peristaltic movements of the duct.

The meeting point or site of impregnation in placental mammals is about one-third, perhaps one-half way down from the fimbria to the uterus. It is remarkably constant for each species. Nothing positive is known as to the site of impregnation in man, but there is no reason to suppose, as is unfortunately often done, that the site is variable or different from that in other mammalia.

In the sexual reproduction of plants the germ cells are brought together in a great variety of ways; and in the higher forms the process is complicated by an alternation of generations. It will suffice for our present purpose to note that in many of the lower plants the male germ cell is an actively motile *spermatozoid,* homologous with the spermatozoon of animals, on the one hand, and with the germ cell of the pollen grain in higher plants, on the other hand.

2. The Entrance of the Spermatozoon into the Ovum and Formation of the Sperm Nucleus.—With our present knowledge, the assumption appears unavoidable that the ovum exerts a specific attraction upon spermatozoa of the same species. We observe, in fact, when artificial fecundation is employed, the spermatozoa swarming around the ova as if held by an irresistible impulse. This phenomenon occurs with every class of animals, even in mammals, whose freshly removed ova were examined on a warm stage under the microscope (Rein). Stassano has maintained that the eggs of echinoderms do exert such an attraction and also a similar but less strong attraction upon the spermatozoa of allied species. Since the brothers Hertwig have found by their experiments with sea urchins that hybrid impregnation takes place more readily after the ova have been kept awhile, Stassano's view involves the further assumption that the specific nature of the attraction fades away during a few hours. Very suggestive in this connection is Pfeffer's discovery that certain chemical substances may attract moving spores, etc., to definite spots. It is conceivable that the ovum may draw the spermatozoa toward itself by chemical influence, acting as an attracting stimulus. That this attraction may be exerted by the cytoplasm of the egg alone, is shown by the experiments of Boveri, Hertwig, Bresi, and Morgan, who found that spermatoza will enter enucleated fragments of eggs.

There may be mechanical devices to facilitate the entrance of the spermatozoon; this is, perhaps, generally true of all ova with micropyles serving for the passage of the spermatozoa. A careful study of such devices in the cockroach has been made by Dewitz, who found that the motions of the spermatozoa of this insect are peculiar, and adapted to increase the probability of their passing through one of the micropyles of the ovum. In ova without micropyles, among which those of mammals are included, the spermatozoa may, so far as we know, penetrate any part of the envelopes.

In the rabbit (Rein) about ten hours after coitus the ovum is found nearly half-way through the oviduct, and surrounded by many spermatozoa, perhaps a hundred, more or less. These are all, or nearly all, in active motion, for the most part pressing their heads against the zona radiata. Several of them make their way through into the interior of the zona. According to Hensen, only those spermatozoa which enter the zona along radial lines can make their way through; those which take oblique courses remain caught in the zona, and may still be seen there during segmentation. As the ovum at this time is already fully matured (see *Ovum*), there is a space between the contracted ovum and the zona. In this space, as well as in the zona itself, several spermatozoa may be observed at scattered points (Fig. 2787). The egg nucleus (see *Ovum*) is present, having been reformed since the expulsion of the second polar globule from the ovum, while in the ovary. One spermatozoon gets into the egg proper, and its entrance apparently prevents the penetration of other spermatozoa—*how* is undetermined. The tail of the spermatozoon soon disappears; while the head, which consists almost entirely of nuclear material, chromatin, enlarges, probably by the imbibition of fluid from the cytoplasm of the egg, and becomes the sperm nucleus. This was formerly called the *male pronucleus*, in distinction from the egg nucleus, which was called the *female pronucleus*; but they differ in no respect from other nuclei, except in the number of chromozomes which they contain.

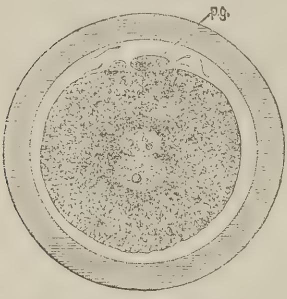

FIG. 2787.—Ovum of a Rabbit (in Optical Section) taken from the Middle of the Oviduct about Seventeen Hours after Coitus. The sperm and egg nuclei are close together at the centre of the egg; the polar globules, *p.g.*, are shown; numerous spermatozoa lie within the zona, *z*. (After Rein.)

The passage of the spermatozoa through the zona was first discovered by Martin Barry, in 1843, and although his statement was received with considerable hesitation by his contemporaries, it has since had competent confirmation repeatedly. Warneck is said to have been the first (1850) to see the *two* pronuclei, but their significance was not perceived. The nature of the male pronucleus was first recognized by Oscar Hertwig, who traced its genesis in the ova of echinoderms from the spermatozoon. The fact that the male pronucleus is the metamorphosed head of the spermatozoon has since been confirmed by Selenka, Ed. van Beneden, Nussbaum, Eberth, Platner, and others.

Although a number of the spermatozoa make their way into the perivitelline space, probably always one alone normally enters the ovum there to form a pronucleus. The best observers are agreed upon this point, and in all species, the observations upon which have covered the whole series of steps in the impregnation, there has been found in normal cases always a single sperm nucleus. Schneider's statements to the contrary have been definitely corrected. Bambeke, Kupffer, and Kupffer and Benecke have observed that several spermatozoa actually enter the yolk in batrachians and Petromyzon. Hertwig, however, found only one sperm nucleus in the frog, and there has as yet been no evidence adduced that several spermatozoa are concerned in the final phases of impregnation. Fol observed that star-fish eggs are normally impregnated by one spermatozoon; but if they are exposed to the action of carbonic acid they may, while so poisoned, be impregnated by several spermatozoa, but the subsequent development in this case is abnormal.

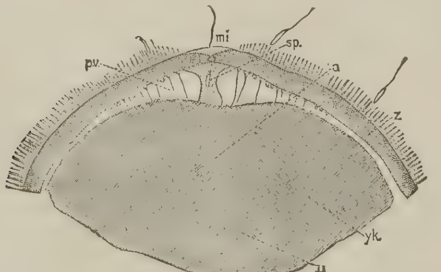

FIG. 2788.—Anterior Pole of the Ovum of Petromyzon, with a Spermatozoon (*sp*)., entering the Micropyle (*mi*). (After Calberla.) *p.v.*, Perivitelline space; *z*, zona pellucida; *a*, pathway to egg nucleus, *n*; *yk*, yolk.

The term micropyle is applied to various structures, and does not in all cases designate a passage through which spermatozoa enter—thus the micropyle of holothurians is merely a structure left in the envelopes in consequence of the way the egg is developed. A micropyle has been observed in the ova of teleosts and the lamprey, but it is doubtful whether it is, like the micropyles in the hard-shelled eggs of insects, intended for the passage of spermatozoa. Calberla saw the micropyle thus used in the lamprey, and it is possible that the fructifying spermatozoon enters that way, although Kupffer and Benecke state that spermatozoa may also pass directly through the zona. A good synopsis of the observations on the lamprey is given by Hensen (Hermann's "Handbuch," vi., ii., 120). We have only to notice that there is a special band of non-granular protoplasm leading from the micropyle to the egg nucleus (Fig. 2788), and serving as a path for the spermatozoon; a similar band has been observed in amphibian eggs by Hertwig and Bambeke; it serves perhaps as a mechanism to guide the sperm nucleus to the egg nucleus.

The manner in which additional spermatozoa are excluded, after the first has entered, is still under discussion. In cases in which there is a single micropyle, which is used for entry, it is possible that a portion of the first spermatozoon may remain to close the passage, or that in going through it sets in action some mechanism by which the opening is automatically shut. Where there are several or many micropyles, as in some insects, or where the envelopes may be pierced at any point, as in mammals, there must of course be some other device. Fol has maintained that this is found in the starfish in the rapid formation of a membrane around the yolk, immediately after the entrance of the first spermatoon. This is confirmed by the observations of Wilson and others on other echinoderm eggs. The egg is at first perfectly naked and the membrane is formed very quickly after the entrance of the head and middle piece, leaving the tail outside. Selenka (*Biolog. Centralbl.*, v., 8) describes the fertilization of the ovum of a nemertean worm —several spermatozoa enter within the vitelline membrane; the yolk contracts slowly; after a time the two polar globules are expelled, and before they separate from the yolk one spermatozoon passes into the yolk between them; the globules then break off and are knocked about by the spermatozoa in the perivitelline space. In this case there seems to be a portal opened just long enough for one spermatozoon to enter. As the phenomenon to be explained is common to all ova, its causation is presumably fundamentally identical in all cases. Beyond this surmise our present knowledge does not permit us to go. The hypothesis may be suggested that the attractive power of the ovum is annulled or weakened by the entrance of the first spermatozoon.

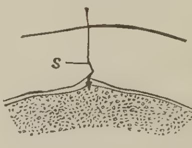

FIG. 2789.—Egg of Toxopneustes, with entering Spermatozoon (*s*), and a Protuberance of the Cytoplasm rising toward it. (After Selenka.)

The fate of the tail of the spermatozoon differs in different species. In some the whole spermatozoon enters the egg, while in others, as the echinoderms, only the head and the middle piece enter. In either case it is a well-established fact that the tail is simply a locomotor organ and takes no part in fertilization proper.

While the spermatozoon is passing through the ovic envelopes active changes occur in the cytoplasm. Of these, the most constant, as well as the most obvious, is the formation of a slight protuberance on the surface of the cytoplasm of the egg, rising up toward the spermatozoon. This protuberance (Fig. 2789) may remain, as in echinoderms, until the spermatozoon meets it, and by penetrating it enters the ovum; or it may retract before the spermatozoon passes through the envelopes, and even withdraw, as in Petromyzon, so far from the advancing spermatozoon as to change into a depression (Fig. 2788). The protuberance lasts only a few minutes. In Bufo, according to Kupffer, several spermatozoa enter the egg and a protuberance rises toward each one, as if the cytoplasm were actively striving to reach the male element.

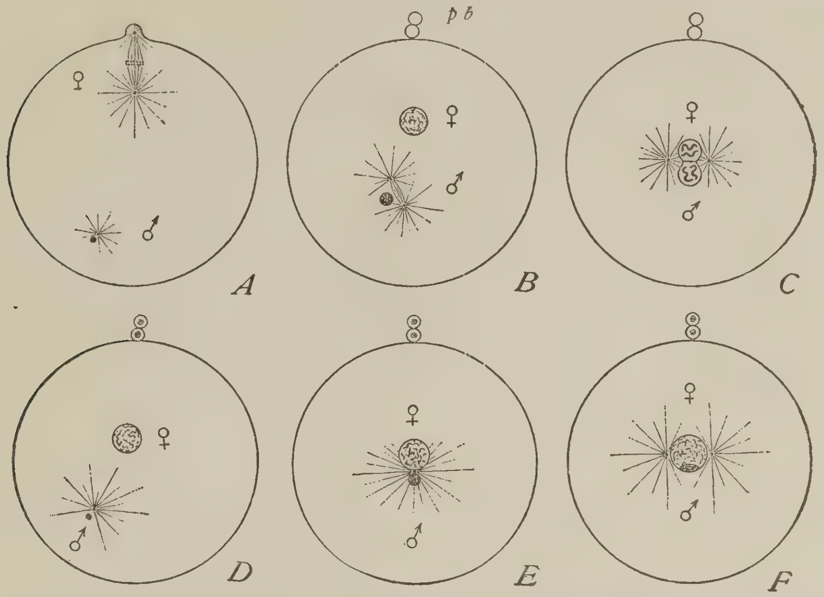

FIG. 2790.—Diagrams of Two Principal Types of Fertilization. *A*, *B*, and *C*, Polar bodies formed after the entrance of the spermatozoon, as in Nematodes, Annelids, and Mollusks; *D*, *E*, and *F*, polar bodies formed before entrance of spermatozoon, as in Echinoderms. Egg nucleus at ♀, sperm-nucleus at ♂. (From Wilson.)

3. FUSION OF THE GERM NUCLEI, FERTILIZATION PROPER.—For many centuries the process of fecundation was wrapped in the deepest mystery, and while the keen observers of the latter half of the eighteenth century and the first half of the nineteenth did much necessary preliminary work in this direction, they so far failed to clear up the mystery that, although spermatozoa had been discovered by Hamm and Leeuwenhoek in 1677, and Spallanzani had shown in 1786 that spermatic fluid deprived of spermatozoa by filtration is sterile, Johannes Müller wrote in his "Physiology" in 1840 that it was uncertain whether the spermatozoa were parasites or not; and, although Schwann had declared the egg to be a cell as early as 1838, it was still possible in 1875 for a distinguished zoologist, Alexander Goette, to write "that the egg was a mass of non-living yolk which, under the influence of the spermatozoon, gradually came into a living condition." While the process is still sufficiently wonderful and mysterious, a great deal has been done during the past twenty-five years to render it intelligible.

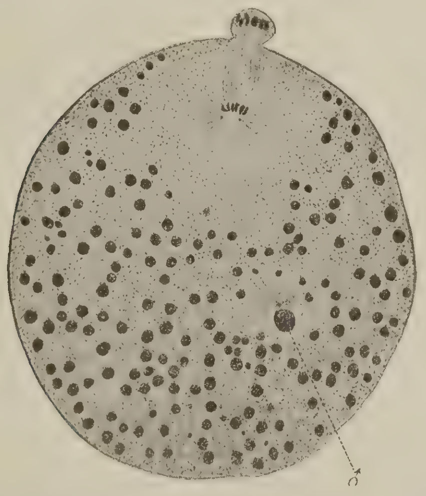

FIG. 2791.—Fertilization of the Egg of *Thalassema melitta*. The head of the spermatozoon preceded by the sperm aster is shown at ♂. The formation of the first polar body is nearly completed and the inner centrosome of the polar spindle has divided preparatory to the formation of the second polar amphiaster. Highly magnified. (After Griffin.)

The first great discovery was made by Oscar Hertwig, who observed in 1875 that the egg of a sea-urchin, *Toxopneustes lividus*, is normally fertilized by the entrance of a single spermatozoon, and that the spermatozoon gives rise to a nucleus which unites with the nucleus of the egg, forming by this union the segmentation, or cleavage, nucleus. We know now, as the result of numerous observations, that both the egg and the spermatozoon are living cells, and that they are morphologically equivalent, except in so far as they are altered in form in adaptation to a physiological division of labor, the principal difference being that the egg is provided with a large amount of cytoplasm, often heavily laden with food yolk for the nourishment of the embryo, and has no power of locomotion; while the spermatozoon is totally devoid of

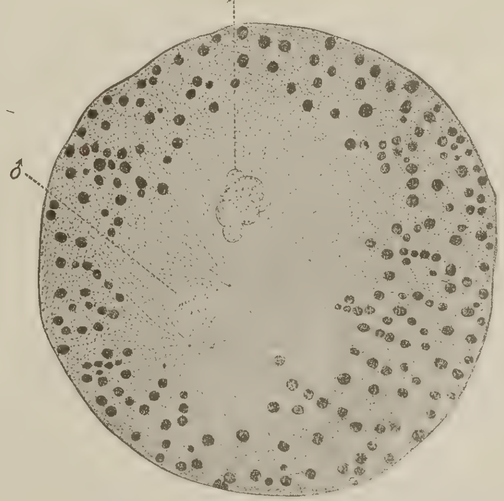

FIG. 2792.—Later Stage of the Same. The egg nucleus is shown at ♀ and the sperm nucleus at ♂. The two nuclei are approaching one another. The egg centrosome has vanished, while the persistant sperm centrosome has divided forming two centrosomes with asters. (After Griffin.)

food material and has but little cytoplasm, most of which is usually modified to form a flagellum or other organ by which the spermatozoon may move actively and seek the egg. There is possibly another physiological difference which will be noticed in connection with the function of the centrosome. The terms male and female cannot be applied properly to these cells, and should be used only as descriptive of the organisms that produce them or their equivalents.

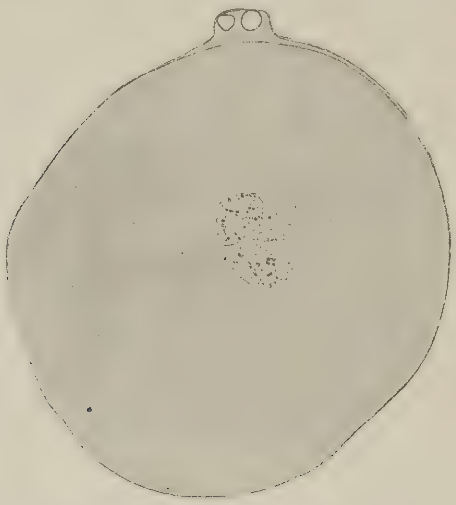

Fig. 2793.—Thalassema. Copulation of the germ nuclei. The sperm centrosomes are seen in the plane separating the two nuclei. (After Griffin.)

There are two types of fertilization in animals, depending, as was first suggested by Hertwig, upon the time of entrance of the spermatozoon.

The eggs of echinoderms (Fig. 2790, *D*, *E*, *F*) pass through the whole process of maturation (see *Reduction Division*) before the entrance of the spermatozoon, the egg nucleus has resumed the form of a spherical vesicle, and the aster and centrosome of the last polar spindle have disappeared. The spermatozoon may enter the egg at any point. Soon after entrance the head of the spermatozoon revolves end for end and begins to enlarge, while a series of lines appear in the cytoplasm radiating from the position of the middle piece. These radiations form the *sperm aster*, and at their centre there is a small darkly staining spot, the *sperm centrosome*. The head of the spermatozoon, now called the *sperm nucleus*, moves rapidly toward the *egg nucleus*, preceded by the aster. The latter touches the egg nucleus and divides into two, and shortly after this the sperm nucleus unites with the egg nucleus, the two becoming completely fused in a single segmentation, or *cleavage, nucleus*. In the mean time the two asters formed by division of the sperm aster have taken up positions at opposite poles of the nucleus. Soon the nuclear membrane disappears, chromosomes and spindle are formed, and the first cleavage begins. In this type of fertilization the two nuclei are of unequal size, the sperm nucleus being much the smaller.

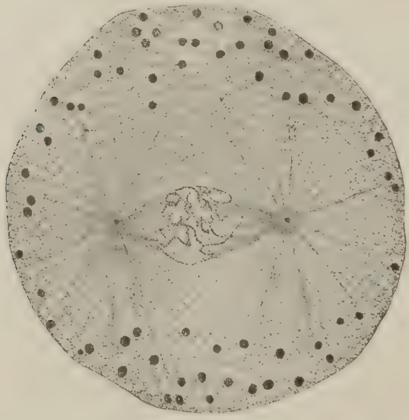

Fig. 2794.—Thalassema. The first cleavage amphiaster. Germ nuclei completely fused, with the chromatin in the spireme stage. (After Griffin.)

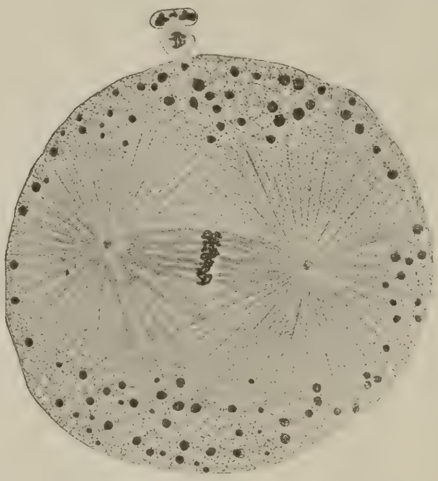

Fig. 2795.—The Same. First cleavage spindle in the late prophase. Chromosomes forming at the equator. The centrosomes have begun to divide preparatory to the second cleavage. This section passes through the plane of the two polar bodies, which are seen at the upper pole of the egg. (After Griffin.)

The second type is seen in the eggs of flat worms, annelids, and mollusks (Fig. 2790, *A*, *B*, *C*). In these groups the whole process of maturation of the egg takes place after the entrance of the spermatozoon, that act being apparently the stimulus necessary to set the process in motion. While the two polar bodies are being formed, the sperm nucleus advances to the centre of the egg and becomes greatly enlarged, and at the same time the sperm

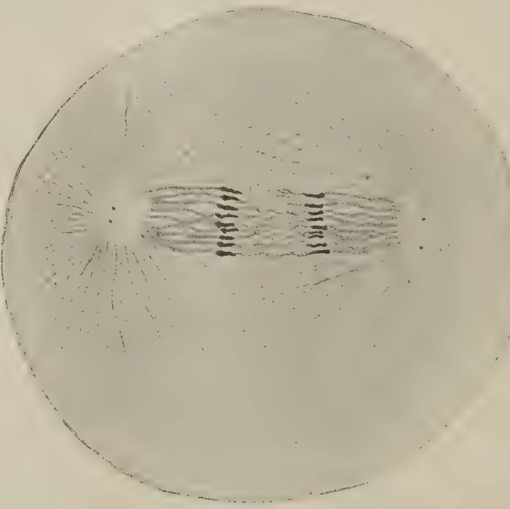

Fig. 2796.—The Same. Cleavage spindle in the anaphase. The chromosomes have divided and are separating to opposite poles. (After Griffin.)

aster divides to form an amphiaster (Fig. 2791). At the completion of the second polar division the egg nucleus is reformed and moves toward the sperm nucleus (Fig. 2792). As a rule the egg aster and centrosome disappear. Finally the two nuclei, now of equal size, lie side by side, but without fusing, with the two asters derived from the sperm aster lying in the plane between them (Fig. 2793). Soon after this the chromosomes reappear in each nucleus, the nuclear membrane fades away, and the first cleavage spindle is formed as before (Figs. 2794, 2795, and 2796).

Between these two types there are various intermediate forms in which the entrance of the spermatozoon occurs either after the extrusion of the first polar body or during some other phase of the process of maturation.

The account given in the preceding paragraphs should be taken as merely a general statement of the main facts of fertilization. The details of the process vary to a greater or less degree in different species. In the slipper shell, Crepidula, for example, the protoplasm flows toward the upper pole of the egg, while the yolk becomes more concentrated in the lower part. This is true probably, more or less, in all eggs that divide unequally. In such cases the union of the germ nuclei takes place near the centre of the protoplasmic mass.

In the first type of fertilization it is impossible to trace the history of the chromosomes of the cleavage nucleus. But in many cases of the second type it is possible to do this very clearly. The eggs of Ascaris are known to be especially favorable objects as the result of the brilliant researches of Boveri, Van Beneden, and Herla. In such cases it has been shown beyond a doubt that of the chromosomes in the cleavage spindle, one-half are derived from the egg nucleus of maternal origin and the other half are in like manner derived from the sperm nucleus of paternal origin (Fig. 2797). Now during the mitosis preparatory to the first cleavage, each chromosome is divided into two and the halves separate to opposite poles of the spindle, so that each daughter nucleus receives an equal number of chromosomes of maternal and of paternal origin (Fig. 2796). The same thing occurs in all subsequent mitoses. Therefore if the chromosomes maintain their individuality during the resting stage, as there is reason to suppose they do (see *Chromosome*), each somatic cell is provided with chromatin derived in equal measure from the two parents. This is a fact of the greatest importance for our theory of heredity (see *Heredity*).

The origin and fate of the centrosomes of the cleavage spindle have been fruitful of much discussion, and the results of investigation are still somewhat contradictory. The majority of observers are agreed now that the centrosome accompanying the egg nucleus after the separation of the second polar body usually disintegrates and disappears before the union of the two nuclei (as seen in Fig. 2792). But Conklin maintains that in Crepidula this centrosome persists, unites with the sperm centrosome, and that the product of this union divides to form the centrosomes of the first cleavage amphiaster. If true, this is certainly exceptional. The sperm centrosome which appears near the sperm nucleus soon after the entrance of the spermatozoon appears to be derived from the middle piece, which in turn was formed from the centrosome of the spermatid (see *Spermatozoon*). At any rate, it appears in the position of the middle piece, or near it. But because of its minute size it cannot, as a rule, be supposed to represent more than a part of the middle piece. Some observers have asserted that it is a new structure that arises in the cytoplasm of the egg as a result of a stimulus from the spermatozoon, with which it has no morphological connection. But the view that it is derived from the middle piece seems to agree best with the observations in most cases. The fate of this centrosome is also a matter of doubt. At least in most cases it has been impossible to show conclusively that this centrosome gives rise to the centrosomes of the cleavage amphiaster. It may disintegrate, and a new centrosome may arise in the cytoplasm close by the united nuclei. But Griffin has asserted positively that in the gepherian worm, Thalassema, he has been able to trace the history of the sperm centrosome continuously to the formation of the cleavage amphiaster. The centrosomes of this amphiaster pass one into each daughter cell during cleavage, and frequently each one divides into two before the first cleavage is complete, in anticipation of the second cleavage (Fig. 2796). This process is continued during subsequent cleavages; so it appears that the centrosomes of the first cleavage amphiaster give rise by division to the centrosomes of all the cells of the embryo, at least for a number of cell generations.

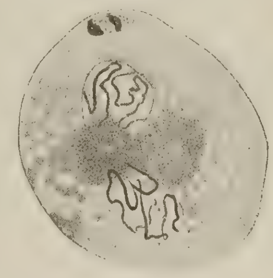

FIG. 2797.—Fertilized Egg of *Ascaris megalocephala* var. *bivalens* just previous to the formation of the cleavage spindle. Two elongated chromosomes have appeared in each germ nucleus. The two large centrosomes are surrounded by extensive masses of granular archoplasm, and the second polar body is visible in the upper part of the section. Highly magnified. (After Boveri.)

As to the function of the centrosome, Boveri maintains that it is a permanent cell organ and that it is the dynamical centre of the cell. The egg centrosome having been absorbed, he regards the sperm centrosome as the especial fertilizing agent introduced into the egg by the spermatozoon. That is, while the sperm nucleus introduces the physical basis for heredity of the paternal characteristics, it is the centrosome that furnishes the stimulus necessary to start the segmentation of the egg and development of the embryo. Boveri finds evidence for this view in certain abnormal phenomena called partial fertilization. He observed that in sea urchin eggs it sometimes happens that the sperm centrosome gets so far ahead of the sperm nucleus that it conjugates with the egg nucleus and causes the egg to divide before the union of the two nuclei. The sperm nucleus, however, subsequently unites with one of the nuclei of maternal origin in the two-cell stage.

Of great interest in this connection are the observations of Hertwig, Morgan, Loeb, and Wilson upon the production of artificial parthenogenesis in unfertilized eggs. Hertwig, using solutions of strychnine, and Morgan, using chiefly solutions of sodium and magnesium chlorides, found that unfertilized echinoderm eggs when treated with these substances might undergo cleavage; and Morgan discovered, moreover, that as a result of this treatment there might appear in the cytoplasm of the egg a large number of asters, each having at its centre an accumulation of material like a centrosome. This last observation would seem to raise a serious objection to the idea that the centrosome is a peculiar and permanent cell organ. Loeb subsequently made the remarkable discovery that by careful treatment with various inorganic salts, and even with sugar and urea, unfertilized eggs of two species of echinoderms and of one annelid could be induced, not only to segment, but to give rise to swimming larvæ. These results have been fully confirmed by Wilson, who has shown that in the case of the sea urchin, Toxopneustes, the eggs, which begin development under the influence of a twelve-per-cent. solution of $MgCl_2$ without fertilization, do not develop a vitelline membrane and contain only the number of chromosomes normally present in the egg nucleus. So there can be no question of accidental fertilization. Wilson has worked out the cytological changes occurring in such eggs. He finds much variation and many abnormalities, which result in the death of the embryo. Where nearly normal development takes place, he finds that always a *new* centrosome with its surrounding aster forms close to one side of the nucleus. It then divides, the two halves passing to opposite poles of the nucleus to form an amphiaster, and then cleavage proceeds very much as usual. If the primary centrosome fails to divide, it may go through certain periodic changes, increasing and decreasing in size, and these changes are accompanied by division of chromosomes in the nucleus, but no cell division takes place. The cleavage of the egg then appears to depend upon the normal behavior of a centrosome closely associated with the nucleus, but this centrosome may be caused to arise *de novo* by appropriate chemical stimuli. It, however, acts much more slowly than the centrosome introduced with the spermatozoon. But the centrosome is not capable of producing cleavage of the cytoplasm unless accompanied by a nucleus. For example, Wilson has found that asters containing centrosomes may be produced by chemical stimulus in enucleated fragments of eggs obtained by shaking unfertilized eggs to pieces. Such asters may multiply by division, but the cytoplasm does not divide. And Boveri has observed that sometimes during cleavage of fertilized eggs all of the chromatin will go to one daughter cell, the other receiving only an aster. In such a case the aster in the enucleated cell will continue to divide, but the cell will not.

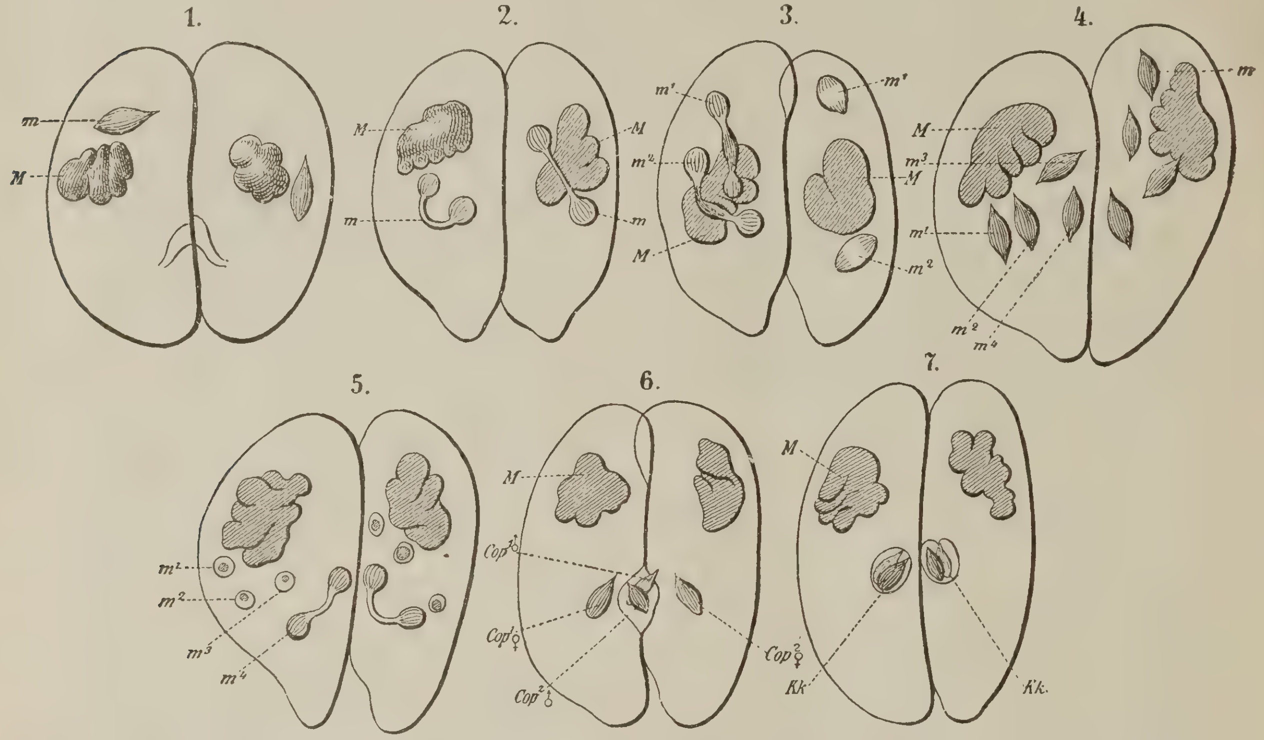

FIG. 2798.—The Conjugation of Infusoria. (From Weismann, after Maupas.) 1, Two infusoria copulating; *M*, meganucleus; *m*, micronucleus; 2–5, successive divisions of micronuclei; 6, fertilization by the migration of one of the persisting micronuclei from each infusorian into the other; 7, union of the interchanged micronuclei.

Hertwig, Boveri, and others have found that if enucleated fragments of unfertilized eggs be mixed with spermatozoa of the same or closely related species, the spermatozoa will enter the fragments, the nucleus will undergo regular mitotic division, the cytoplasm will divide, and larvæ will be produced that are indistinguishable from normally produced larvæ, except for their smaller size. The sperm nucleus is, then, perfectly equivalent to the egg nucleus and only needs to be supplied with the necessary envelope of cytoplasm in order to undergo the same series of changes; and under certain conditions the normal cycle of life may be inaugurated by either the sperm or the egg nucleus without union with the other, even in species in which normal parthenogenesis is unknown.

The process of fertilization in plants has not been studied so extensively as in animals. But enough has been learned to show that, so far as the nucleus is concerned, the process is essentially the same. In the sexual reproduction of all plants that have been examined, it has been found that fertilization is effected by the union of a single germ nucleus of paternal origin with the egg nucleus. This was described for the first time by Strasburger in 1884, and his results have been confirmed by Guignard and a number of other investigators in a variety of plants of various orders. In some plants the paternal gamete is an actively motile spermatozoid, in others it is an immobile cell that reaches the egg cell by a process of growth, as is the case with the pollen tube of the higher plants. But in all essential features the process is the same in both cases.

Although Guignard, in 1891, described with much detail a conjugation of centrosomes in connection with fertilization in the lily, his results have not been confirmed; and most observers have failed to find any evidence of a centrosome in any way connected with either of the conjugating nuclei of plants. This would seem to indicate that the presence of a centrosome is not essential to fertilization. But Strasburger has found that a centrosome appears in Fucus on the side of the cleavage nucleus that is derived from the sperm nucleus, and Wilson approves of his suggestion that in plants "the sperm nucleus may import into the egg either a formed centrosome (probably thus in Fucus) or a certain quantity of 'kinoplasm' which excites the mitotic phenomena in the absence of individualized centrosomes."

The pollen tube of angiosperms contains two sperm nuclei, of which only one unites with the egg nucleus. In 1898 Nawaschin published the interesting discovery that in *Lilium martagon* and *Fritillaria tenella* the other sperm nucleus conjugates with the two "polar nuclei" to form the embryo sac nucleus, the division of which gives rise to the endosperm of the seed. The same phenomenon was described more in detail by Guignard in 1899, and confirmed by Miss Sargent. It immediately occurred to De Vries, and independently to Webber, that this might explain a phenomenon called *xenia* by Focke (1881). For a long time it has been known that if the pollen of one variety of maize be allowed to fall upon the silk of a different variety, the kernels in the ear may show the characters of the male parent. Until this process of double fertilization was discovered, the embryo was the only part known to have a double origin, and the appearance of the paternal characters in a part of the seed supposed to be purely of maternal origin seemed very mysterious.

From a careful study of the phenomena of xenia in maize, in which the only undoubted cases occur, Webber has reached the conclusion that they are perfectly consistent with the theory of double fertilization, no xenia appearing in characters not connected with the endosperm. But the actual double fertilization has not yet been observed in this plant.

Xenia has been supposed to be a similar phenomenon to *telegony* in animals. But it seems impossible for any such process of double fertilization to occur in animals, and Ewart has found that in the mare "the spermatozoa lodged in the upper dilated part of the oviduct are dead, and in process of disintegrating, eight days after insemination." Moreover, the supposed existence of telegony has been entirely discredited by Ewart on experimental evidence, and by Pearson on evidence from statistics.

In the conjugation of the unicellular animals and plants, we find a process clearly analogous to the fertilization of the higher groups. The two conjugating cells may be similar or diverse in form. In many motile Infusoria (Fig. 2798) two similar individuals come together, exchange nuclei, each one giving off a "male pronucleus," which enters the body of the other and unites with its "female pronucleus," and then the two separate. In other cases there is a motile "microgamete" that forms a permanent union with a sessile "macrogamete," comparable to spermatozoon and egg respectively. In each case the essential feature of the process is a union of two equivalent nuclei, preceded and followed by a complicated series of divisions that we need not discuss here.

Summing up the subject of fertilization, Wilson says ("The Cell," ed. 2, p. 230): "We thus find the essential fact of fertilization and sexual reproduction to be a union of equivalent nuclei; and to this all other processes are tributary." The almost universal occurrence of this process in animals and plants of all grades, from the protozoa to man, indicates that it has some profound significance, but what this is is unknown. According to Weismann, fertilization has for its object the mingling of ancestral germ plasms and the consequent production of variability in the offspring. But Pearson, as the result of statistical investigations, holds that variability is not produced by fertilization. According to Maupas, fertilization has for its object a rejuvenescence of protoplasm, which thus wards off the senescence and "natural death" that must inevitably overtake it if fertilization does not take place; and Minot finds evidence for this view in the results of his investigations of the law of growth (see *Growth*). But when we consider the innumerable generations of domestic plants that have been produced with unimpaired vigor by cuttings, grafts, and other purely asexual methods of reproduction, the existence of any such "natural death" appears to be extremely doubtful. So while our knowledge of the details of fertilization has advanced enormously during the past quarter century, the origin and object of the process remain as mysterious as ever.

Robert Payne Bigelow.

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INCOMPATIBILITY, MEDICINAL.—The word *incompatible*, used in connection with the mutual relations of medicines, is one of very loose application. Thus, in a sweeping way, a medicine is said to be *chemically* "incompatible" with anything that will produce a chemical or physical change in its condition, and *physiologically* "incompatible" with anything that produces the reverse of its so-called physiological effects. Under these definitions, however, it is evident that in many cases so-called "incompatibility" may yet not interfere at all with full medicinal power or purpose. Practically, the subject of medicinal incompatibility deals with those chemical, physical, and physiological mutual relations of medicines that require consideration in the prescription of different medicinal substances in conjunction, and such topic it is that will here be considered.

As regards *chemical* and *physical* reactions there are many which are special, between special medicines. Such must be learned in connection with the individual medicines concerned. But, also, there are certain reactions that affect broad categories of medicines, and which, therefore, admit of general consideration. Such reactions and the practical bearings thereof in prescribing are as follows:

1. *Acids and bases tend directly to combine, to form salts.* This reaction may be utilized, if it be the object of the prescriber to obtain the salt that will result from the bringing together of an acid and base; but if the purpose of the prescription be to retain free acidity or alkalinity, acids and bases must not be conjoined in prescription.

2. *Stronger acids or bases tend to displace, in the case of salts in solution, weaker bodies of their own respective kinds.* Thus, if sodium carbonate in solution be treated with nitric acid, the nitric acid will displace the carbonic to the formation of sodium nitrate in solution and the evolution of carbon-dioxide gas. Strictly speaking, the statement of this reaction is a *circulus in definiendo*, since one acid is known to be "stronger" than another only by

TABLE OF NOTABLE MUTUALLY PRECIPITANT SOLUTIONS.

	Solutions of alkalies.	Carbonic acid and solutions of carbonates.	Sulphuric acid and solutions of sulphates.	Phosphoric acid and solutions of phosphates.	Boric acid and solutions of borates.	Hydrochloric acid and solutions of chlorides.	Hydrobromic acid and solutions of bromides.	Hydriodic acid and solutions of iodides.	Solutions of sulphides.	Tannic acid.	Arsenical solutions.	Albumin.
Alkaloidal solutions (generally)	Prec.	Prec.	......	Prec.	Prec.	......	......	Prec.	......	Prec.	......	......
Metallic solutions (generally)	Prec.	Prec.	......	Prec.	Prec.	......	......	......	Prec.	Prec.	Prec.	Prec.
Lead solutions	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.
Silver solutions	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.	Prec.
Calcic solutions	Prec.	Prec.	Prec.	Prec.	......	......	......	......	......	......	......	......
Magnesic solutions	Prec.	Prec.	......	Prec.	......	......	......	......	......	......	......	......
Albuminous solutions	......	......	......	......	......	......	......	......	......	Prec.	......	......
Gelatinous solutions	......	......	......	......	......	......	......	......	......	Prec.	......	......

the fact of its supplanting such other acid in saline combination, in solution. The statement, however, is a convenient reminder, to the prescriber, of a set of reactions which are of common occurrence, and whose bearing upon prescribing is as important as it is obvious.

3. *Salts in solution tend to exchange radicals; or acids, or bases, to displace their respective brethren in saline combination, if thereby an insoluble compound will form.* If, as the cant phrase runs, nature "abhors a vacuum," she also *delights in precipitates;* for reactions, determined evidently by the fact that a precipitate will result, are among the commonest occurrences of chemistry. Concerning this reaction it is to be noted that while precipitation may affect potency profoundly in the case of some medicines, in other cases it may make no difference or may be of distinct advantage. Thus in the case of the so-called black and yellow washes of mercury, it is a precipitate which is wanted, and which therefore is intentionally the subject of prescription. Generally, however, the occurrence of a precipitate in a medicinal mixture is objectionable; for, even if medicinal virtue be not affected, the turbidity is unsightly, and, by the settling of the precipitate as the bottle stands, doses drawn, on the one hand, from the full or, on the other, from the nearly empty vial will vary enormously in strength of the precipitated ingredient, unless the bottle be thoroughly shaken at the taking of each dose. The table of *notable* mutually precipitant solutions, taken from the writer's "Manual of Medicinal Technology" (see at the foot of page 853), is convenient for reference. The reactions therein broadly stated as occurring with solutions of salts of the *alkaloids*, and of the *metals*, are true in the *generality* of instances only.

4. *Things in solution precipitate on addition of an excess of a fluid in which they are respectively insoluble.* Here, as in the former instance, precipitation may not affect medicinal potency, but yet is generally to be avoided because of the intrinsic objections to precipitates in medicinal mixtures, as set forth above. The two medicinal solvents most concerned in the present relation are *water* and *alcohol*, and the commonest instances of the reaction in question are as follows: *albuminous, gelatinous, gummy, saccharine*, and certain *saline* bodies dissolve in water but are insoluble in alcohol, and accordingly precipitate on addition of an excess of alcohol to their aqueous solution; while, *vice versa, alcoholic* solutions of *volatile oils, balsams, camphor*, and *resins* precipitate on treatment with excess of water.

5. *Powerfully oxidizing agents may determine explosions on concentrated admixture with readily oxidizable substances.* The exact conditions determining explosions with individual mixtures of this category will vary with the substances concerned, and must accordingly be learned with each medicine. All that is appropriate to state in this place is that the powerful oxidizers used in medicine are *chromic* and strong *nitric* or *nitrohydrochloric acids, potassium chlorate*, and *potassium permanganate;* while the medicinal substances of easy combustibility are *oils, alcohols*, and *ethers* (including in the latter categories *glycerin* and *sugars*, bodies chemically belonging to the alcohols), dry *organic* substances generally, and the elementary bodies, *sulphur* and *phosphorus*.

Physiological incompatibility, as already stated, is alleged between medicines whose respective so-called "physiological" effects are mutually antagonistic. Such antagonisms are individual and peculiar, and are best discussed in connection with the individual medicines concerned. Two points alone are proper subject for mention in this place. The first is that *exact* antagonism in *all directions* of physiological action of drugs is very rare, and the second, that in practical prescribing the fact of an antagonism need not preclude the proper conjunction of two antagonistic medicines in the same mixture. On the contrary, many of the happiest of medicinal combinations are of remedies more or less antagonistic in operation; this either because the antagonism is itself serviceable in mellowing a too intense action of the dominant antagonist, or because the drugs, though antagonistic in some lines, are synergic in others, and so together yield a resultant effect better for certain remedial purposes than the unmodified effect of either medicine used singly. An example of the former instance is the common combination of castor oil and laudanum; and of the latter, the association of atropine with morphine.

Edward Curtis.

INDIAN HEMP. See *Cannabis Indica.*

INDIAN MINERAL SPRINGS.—Kendall County, Texas.

Post-Office.—Boerne. Boarding-houses.

The town of Boerne is located about thirty miles northwest of the city of San Antonio, on the line of the San Antonio and Arransas Pass Railroad. The country has a general elevation of about 1,670 feet above the sea. The general aspect of the country is very pleasing, being quite hilly, even rugged in places. There are many beautiful drives and fine views. The town of Boerne has a population of about 800. It contains a telegraph and express office, very good hotels and boarding-houses. Four trains daily reach the place. From data furnished by the National Climatological Reports it is found that the average number of sunny days in each year is 277, and that invalids can enjoy more or less outdoor life 350 days yearly. The average summer temperature of the place is 85° F.; winter temperature, 62° F. It is said that a cooling southeast breeze from the gulf prevails all the year and greatly tempers the heat of the summer sun, making the evenings and nights cool and pleasant. The location is beginning to attract the attention of Northern visitors, who visit the place in constantly increasing numbers during the winter months. The Indian Mineral Spring is located three miles from Boerne, from which it is reached by stage and private conveyances. The water is said to be efficacious in a variety of debilitated states, besides being a valuable table water. A partial examination was made by Prof. Charles F. Chandler, of New York. It showed the presence of 138.38 grains of solids per United States gallon, consisting principally of calcium, magnesium, and sulphuric acid in the form of sulphates. A more detailed analysis will be required to classify the water properly. *James K. Crook.*

INDIAN SPRINGS, BUTTS COUNTY, GEORGIA.—

Post-Office.—Indian Springs. Several hotels in village.

Access.—Viâ Macon and Western Railroad to Forsyth, thence by stage line to spring. This celebrated spring received its name on account of its great reputation as a medicine spring among the Indians. In the treaty of 1821, when all this portion of Georgia was ceded to the whites, a special reservation of one-thousand acres, including Indian Spring, was made by the Creek nation. This, however, was given up to the whites a few years later. In 1823 General McIntosh erected a small hotel, which is still used for its original purpose (Duggan). A village of three hundred or more inhabitants has sprung up in the neighborhood. The following analysis was made by Prof. A. A. Hayes a number of years ago:

One United States gallon contains 648.03 grains of solid matter consisting chiefly of the following ingredients.

Magnesium sulphate.
Magnesium carbonate.
Calcium sulphate.
Potassium sulphate.

Gases { Carbonic acid .... 2.61 cubic inches per gallon.
Gases { Hydrogen sulphide...... 1.05 " "

The water contains an exceedingly large amount of sulphate of magnesia or Epsom salts. When to this is added the considerable quantity of other sulphates we have a very valuable mineral water. There is sufficient calcium sulphate to exert a useful influence in diseases of the urinary apparatus and also to modify the purgative effects of the sulphate of magnesia. Among the numerous affections in which the water has been found useful may be mentioned dropsical affections when not due to heart disease, rheumatism, and tertiary syphilis.

James K. Crook.

INDIAN SPRINGS, MARTIN COUNTY, INDIANA.—Post-Office.—Indian Springs. Hotel for 500 guests. Hacks meet all trains during the season. The resort is located eight miles north of Shoals, the county seat of Martin County.

The therapeutic value of the waters of these springs has been known for years, and they were in great repute among the aborigines. The springs were first opened to the public as a health resort in 1814, and they have maintained their reputation ever since. They have their source along the course of Sulphur Creek, which wends its way through the surrounding valley and empties into the Indian Creek one mile distant from the hotel. The surrounding country is hilly and quite picturesque. The following analysis was made by Prof. E. T. Cox, State Geologist:

One United States Gallon Contains:

Solids.	Grains.
Sodium carbonate	3.65
Magnesium carbonate	18.95
Calcium carbonate	33.10
Potassium carbonate	2.40
Sodium sulphate	11.83
Potassium sulphate	2.40
Magnesium sulphate	30.40
Aluminum sulphate	.82
Iron sulphate	20.23
Sodium chloride	39.38
Magnesium chloride	.06
Bromides	Trace.
Iodides	Trace.
Iron oxide	Trace.
Silica	.45
Total	163.67
Gases.	**Cu. in.**
Carbonic acid	9.58
Sulphureted hydrogen	3.33
Oxygen	3.95
Nitrogen	6.45

This water is a powerful chalybeate, also a fairly strong alkaline-saline water. *James K. Crook.*

INDIANA MINERAL SPRINGS AND MUD BATHS.—Warren County, Indiana.

Post-Office.—Indiana Mineral Springs. Hotel. This new resort is located four miles from Attica, at the junction of the Wabash and the Chicago and Eastern Illinois railroads. Stages from the springs meet all trains. Although but recently improved, this resort is rapidly coming into popular favor. A first-class hotel, with all modern improvements, has been constructed, and an elegant and commodious bath-house is ready for the requirements of visitors. The naturally picturesque location has already been much beautified by the landscape gardener and architect. The water of the springs is said to be pure and sparkling and pleasant to the palate. A recent qualitative analysis (May, 1893) under the direction of the manufacturing chemists, Messrs. Parke, Davis & Co., Detroit, showed the following ingredients: Total solid residue from one gallon, 20.21 grains, made up of the salts of magnesium, sodium, lithium, calcium, potassium, and silicon. The chemist also reports the presence of sulphuric and hydrochloric acids (probably in combination). There was no organic matter, and the water was highly carbonated. A special feature of the place is a deposit of inky black mud surrounding the springs, and said to be strongly impregnated with the mineral ingredients of the water. This mud is warmed to the proper degree and applied by an attendant to the affected parts—the whole body, if required—in the form of a poultice. About one hour is required for a mud bath, when the patient passes under a shower bath and remains until all traces of the mud are removed. He is then placed in a porcelain-lined tub filled with lithia water for a soaking; then comes a refreshing rubbing by the attendant, and the bath for the day is ended. These baths are said to be very beneficial in cases of obstinate rheumatism, in hemiplegia, and in eczema and gout. The internal use of the water is indicated in renal and bladder affections.

James K. Crook.

INDIANAPOLIS, INDIANA.—The largest city and capital of Indiana is situated near the centre of the State, 195 miles southeast of Chicago. An index of its climate is here given for the sake of reference and comparison.

Climate of Indianapolis, Ind.—Latitude, 39° 46′; Longitude, 86° 10′. Period of Observation, Eleven Years Nine Months.

	January.	March.	May.	August.	November.	Year.
Temperature—						
Average or normal	20.9°	40.3°	64.3°	74.3°	40.7°	53.2°
Average range	15.1	16.3	18.9	18.4	14.0	
Mean of warmest	36.5	49.9	73.8	82.9	49.1	
Mean of coldest	21.4	33.6	54.9	64.5	35.1	
Highest or maximum	69.0	77.0	89.0	101.0	75.0	
Lowest or minimum	−22.0	9.0	31.0	48.0	− 5.0	
Humidity—						
Average relative	73.6%	67.0%	60.3%	68.5%	69.9%	67.7%
Wind—						
Prevailing direction	W.	N. W.	S. E.	S.	N. W.	N. W.
Average hourly velocity in miles	6.4	7.3	5.7	4.5	5.8	5.7
Weather—						
Average number clear days	5.3	6.5	9.5	11.0	6.1	94.8
Average number fair days	10.5	10.6	12.5	14.1	10.2	142.4
Average number clear and fair days	15.8	17.1	22.0	25.1	16.3	237.2

As will be seen, it is a temperate climate, with considerable seasonal extremes and diurnal fluctuations of temperature. The humidity is not high, and the rainfall is moderate. More than a quarter of the days in the year are clear, more than a third fair, and about two-thirds clear and fair.

Such a climate is well-situated for a residence for those in ordinary health. For the delicate or sick, a change might be advised to escape the cold of the winter and the heat of the summer, and in order to obtain purer air than a city affords. As the elevation is low, a change also to a high altitude might be beneficial for various morbid conditions. *Edward O. Otis.*

INDIGO, WILD.—Baptisia. *Dyers' Green Weed.* Under these names, the herb, and more particularly the root, of *Baptisia tinctoria* (L.) R. Br. (fam. *Leguminosæ*) has been more or less used in domestic, and to a slight extent in professional medicine. Its common names come from the fact that it has been used as a poor substitute for indigo.

The plant is a large, much-branched perennial herb, very abundant in sandy soil, especially in the borders of woods, throughout the Eastern United States. It is said to contain two glucosides, *baptin* and *baptisin*, and the poisonous alkaloid *baptitoxine*, which is believed to be identical with *cytisine*. According to the dose, the properties vary from stimulant, increasing peristalsis and acting as a laxative, to irritant, producing purging and vomiting. Upon the nerve centres, it is primarily stimulant, secondarily depressant or paralyzant, and causing death by paralysis of respiration. Its use has been chiefly, both systemically and locally, in diphtheria, scarlet fever, and sore throat. The dose of the fluid extract is 1 to 4 c.c. (♏ xv. to lx.). *Henry H. Rusby.*

INEBRIETY. See *Insanity: Alcoholic and Drug Intoxication and Habituation.*

INFANCY.—Under the term *infancy* (inability to speak) we include that early period of life which extends from birth to the close of the first dentition. Its first few weeks represent a period of great feebleness during which there exists a liability to special forms of disease consequent upon the great change which takes place in the circulation at birth, and upon the assumption by the several organs of their special work in the economy. To the infant at this period the name of "the new-born" (neonatus) is frequently applied. From the end of the first month to the close of lactation between the ninth and twelfth months is sometimes referred to as the period of early infancy and corresponds to the term "Säuglingsalter" of German writers.

Compared with childhood and adult life, infancy is characterized by rapid growth and development. It is a period specially liable to disease, some of the manifestations of which are peculiar to it; others, though similar to what we meet with in adult life, are more or less modified by the peculiarities of the infant constitution. Its mortality is much greater than that of adult life.

Anatomical and Physiological Characteristics.—The first act of the new-born is to inspire. With the separation of the placenta from the maternal connection and the tying of the cord, the whole circulation of the infant is profoundly altered; for the first time a full current of blood distends the pulmonary arteries to meet air in the newly opened vesicles of the expanding lungs. The thorax is enlarged and the diaphragm and abdominal viscera are depressed, all conspiring to favor the associated changes which take place in the heart. With the sudden deflection of blood to the pulmonary circulation and the greatly increased intrathoracic pressure, the flow of blood through the foramen ovale and the ductus arteriosus comes almost to a standstill, and both these passages become gradually obliterated. Within thirty-six hours Vogel found the ductus arteriosus scarcely large enough to admit a probe; the foramen ovale closes more slowly, the border of the valve usually remaining free for some months, but the foramen is so completely covered that no detriment to the circulation ensues. The left ventricle now takes on the burden of the systemic circulation, rapidly increasing in muscular power so that at the end of the second year its walls are double the thickness of those of the right side.

With the establishment of respiration the livid hue of the skin, due to the interference by parturition with the fœtal circulation, is rapidly exchanged for the deep red of the new-born infant. This hue fades in a few days and the skin not infrequently then assumes a more or less yellow tinge unaccompanied by any symptoms of systemic disorder. This condition is known as *icterus neonatorum;* its true cause is still uncertain, but it is supposed to be associated with the disturbance of the hepatic circulation due to the alteration in its blood supply. This yellow tinge gradually disappears of itself, and by the third week of life the skin assumes the rosy tint of healthy infancy. The fine soft hairs which at birth frequently cover almost the whole body generally fall out by this time and are not renewed, though feeble infants may retain them for some time. The long strong hairs on the scalp with which many infants are born fall out at a later period and are generally replaced by finer and, as a rule, lighter-colored hair. At birth the lachrymal and sudoriferous glands are inactive. It is almost impossible to produce sensible perspiration in an infant a few weeks old; not until after the third month does the activity of the sweat glands commence, but after this age in rachitic infants, perspiration is often very profuse. The sebaceous glands, on the other hand, are very active in the new-born. In the third month the secretion of those in the scalp frequently gives the vertex the appearance of having been smeared with wax, and later on forms a distinct crust of a yellowish-brown color (seborrhœa capillitii) portions of which can be easily removed by the finger nail, when the subjacent skin will be found in a healthy state, not even congested. This excessive secretion ceases spontaneously about the end of the first year, and the scabs, if still remaining, dry and crumble away.

Fat is abundant in the subcutaneous tissues of the healthy infant but is generally absent from the interior of the body. The muscles in the first months are small and soft; not till after the sixth month can they be felt firm and resisting. The bones are still in great part cartilaginous and possess, therefore, much greater flexibility than in the adult.

With the introduction of air the compact tissue of the fœtal lung is converted into a spongy alveolar structure of a rose-pink color and expands so as to cover in great part the pericardium and to come into contact with almost the whole extent of the thoracic wall. The approximation anteriorly of the two pleural cavities, however, is not so close as it becomes in later life, the anterior aspect of the heart and thymus gland remaining comparatively uncovered. The thymus gland, situated partly in the thorax and partly in the lower region of the neck, is in the new-born of large size and increases till about the close of the second year when it ceases to develop; it presents much variation, however, in size and shape. After the eighth year it rapidly decreases in size. Its functions have not yet been ascertained, but it would appear to be connected with the formation of the blood cells. The thyroid gland in the infant is relatively larger than in the adult.

The liver at birth is large and its lower margin is easily felt from 1 to 2 cm. below the ribs. The stomach occupies a more vertical position than in the adult owing to the slight development of its fundus. Its capacity at birth is somewhat less than one ounce.

In the infant the shape of the duodenum is not unlike its form in adult life; its folds are less developed, and more than in the adult does it act as a digestive reservoir where the food from the stomach is mingled with the secretions of the liver and the pancreas. Below the duodenum the several portions of the intestines show considerable difference in their relative lengths as compared with those which they attain in the adult. Both small and large intestines are relatively long; Treves states that the average length of the small intestine at birth is nine feet five inches and of the large, one foot ten inches, and says there is remarkably little deviation from these figures. He estimates that the small intestine grows about two feet per month for the first few months, but after this period development proceeds irregularly, depending upon the nature of the food, the vigor of the digestive process, and the activity of the abdominal nervous centres; it bears no relation to the general growth of the body nor to the weight of the child. The position of both small and large bowel is much less fixed than in the adult; the upper part of the small bowel may frequently be found occupying the lower part of the right iliac fossa, and the caput coli may be found near the umbilicus from which position the colon ascends toward the left hypochondrium. Both ascending and transverse colons are generally very short, while the descending colon and sigmoid flexure are of great comparative length. For the first four months the growth of the large bowel is relatively slight, but a certain amount of readjustment of its position appears to take place by which the ascending and transverse portions increase at the expense of the sigmoid flexure. After the age of four months, however, growth generally goes on steadily. Occasionally this undue length of the sigmoid flexure persists during infancy, seriously impeding the passage of the fæces and leading to constipation.

At birth the kidneys are of comparatively large size and distinctly lobulated. This peculiarity in form gradually passes away, and by the close of infancy they have the same shape as in adult life, though still relatively large. Anomalies are occasionally found. The suprarenals at birth are as large as in the adult. The bladder in the new-born has a capacity of from two to four drachms and lies partly in the pelvis, and partly above it in the abdominal cavity. Renal secretion commences early, and at birth urine is normally present in the bladder and should be voided during the first twelve hours of life. During the first few weeks of life crystals of uric acid and urates, occasionally hyaline casts and epithelial cells with a minute amount of albumin, may be found in the urine, a result of the prenatal condition known as uric-acid infarction. During infancy the urine is of a light color, low specific gravity (1.004–1.010), faintly acid in reaction, and contains a low percentage of urea and of the inorganic salts. The amount of urine passed for the first few days is very variable and has been estimated at from two to three ounces, increasing in the second week to five or ten ounces. Throughout infancy the amount of urine passed is relatively larger than in adult life, but is dependent partly upon the amount of liquid taken by the infant; micturition is very frequent.

The urethra in the male is 6 cm. long, delicate and distensible and generally presents a marked constriction at the meatus. The glans penis is closely invested by the prepuce; cohesion is frequently very firm between the membrane covering the glans and that covering the prepuce. Congenital deformities due to arrested development are not infrequent. In the female infant the urethra and vagina are relatively large and distensible; the uterus is from an inch to an inch and a quarter long, but its fundus is quite undeveloped. Deformities occasionally arise from the non-absorption of the septum formed by the infolding of the cloaca. The mammary gland is well developed, possessing secreting structure in both sexes.

Although the brain of the new-born is of relatively large size, the anterior lobes and the cerebellum are comparatively small, and the fissure of Rolando is much less vertical than in later life. The brain tissue is of a nearly uniform whitish color and of soft pulpy consistence, and contains a large percentage of water. Not till after the close of the first month does gray matter make its appearance on the convolutions. The centres in the medulla and in the spinal cord are in a much more forward state of development than those in the cerebrum, and throughout infancy maintain their functional superiority; of those in the spinal cord the motor centres in the anterior cornua are more developed than those of sensation in the posterior; to this forward state of development of the spinal centres is due the great reflex excitability of the nervous system in infants. So much is this the case that the infant at birth has been termed "a spinal system man."

Circulation.—The blood of the new-born contains a large amount of hæmoglobin, twenty-two per cent. of its solid constituents, but the amount of fibrin is small and the total amount of blood in the body is less than it is in the adult; for this reason infants bear loss of blood badly. The blood cells also for the first few weeks show much variation in size and shape. These conditions, however, soon change; the amount of hæmoglobin at once begins to decrease, reaching its minimum about the sixth month when it remains stationary until after the first year and then begins to increase again; the fibrin rapidly increases in amount. After the first few months the infant has more blood in proportion to its weight than the adult, but the blood is of low specific gravity, has less fibrin, less salts, less hæmoglobin, less soluble albumin and more white blood corpuscles than that of more adult life.

Although at birth the heart as a whole is relatively larger than in the adult, it has to be remembered that in intra-uterine life the auricular half is unduly developed, and that after birth the walls of the left ventricle only slowly acquire that increase of power demanded by their newly assumed burden of the systemic circulation. The arterial system of the infant has also a large relative capacity as compared with the size of the heart, which, associated with a comparatively weak ventricle, renders arterial tension low. This condition persists in some degree till puberty, when it ceases owing to the rapid development of the heart at that age. It would appear that in the young growth and physiologically low blood pressure go hand-in-hand (Jacobi). It is also to be noted that the growth of the large arterial trunks in the infant is not uniform: the subclavian and carotid at birth are relatively large, corresponding with the greater development of the head and upper extremities; after birth the descending aorta and the femoral and renal arteries increase more rapidly in size, corresponding with the rapid growth of the lower extremities.

The pulse rate during infancy is much more rapid than during childhood or adult age, and is easily disturbed and quickened by slight causes; irregularity of rhythm may not infrequently be noted. A girl's pulse is almost always a few beats more rapid than that of a boy. The following table furnishes approximately the pulse rate at various periods:

TABLE SHOWING PULSE RATE AT DIFFERENT PERIODS OF INFANCY.

At birth	From	120-140
At six months	"	110-120
At twelve months	"	105-115
At two years	"	90-105
At five years	"	80-90

Muscular exercise or excitement will increase this rate by from twenty to fifty beats.

The lymphatic system in the infant is well developed; its glands are numerous and large in size, and the intercommunication between them and the general system is more marked than at any other period of life.

Respiration in the infant, as a consequence of the circular shape of the chest, is chiefly carried on by the diaphragm. Owing to the compressibility of the chest wall, to the lack of development in the respiratory muscles, and the yielding character of their points of origin and insertion, and also to the narrowness of the upper air passages, respiration is easily disturbed and in young infants may not infrequently be observed to be irregular. The rate and rhythm of the respiratory movement are very variable; Eustace Smith gives 40 or perhaps more as the number of respirations in the new-born, but adds that they soon become less rapid. Rotch places them at about 45 for the first weeks of life, and in infants under two years at between 20 and 40 per minute. The ratio between the rapidity of the respiration and that of the pulse for the first few months of life is inconstant and easily disturbed. During infancy more oxygen is inhaled and more carbonic dioxide exhaled than in adult life, as the result of the more rapid tissue change. Infants, however, stand complete deprivation of air for a longer period than will adults. Attention is drawn by Jacobi to the greater labor required by the organs of both circulation and respiration in the infant as compared with those of the adult, while at the same time their own development must go on. Hence fatigue is more easily experienced and rest and sleep are much more urgently demanded.

The Digestive Tract.—The mouth is early moistened by secretion from the buccal and labial glands, though in the first days of life often imperfectly so. Saliva is secreted at this date only by the parotid glands; its amount for the first two or three weeks is but one-tenth of what it becomes after the sixth month; not until after the fourth month do the submaxillary glands assume activity. Even in the first days of life, pepsin is secreted by the gastric follicles in small amount. For the first few weeks the stomach is small in size, somewhat tubular in shape, and plays a comparatively unimportant part in the process of digestion, acting chiefly as a receptacle in which the milk is coagulated by the rennet ferment, and from which it passes in a comparatively undigested state into the duodenum where digestion is completed by the pancreatic ferments. While in a breast-fed infant two months old the stomach empties itself in an hour and a half, in an infant four months old the average time is about two hours. Infants fed on cow's milk require half an hour longer. At birth the average capacity of the stomach is under an ounce; the organ, however, increases rapidly in size, and by the end of the fourth week its capacity in an infant of average size is about two and a half ounces, at three months four and a half ounces, at six months six ounces, and at twelve months nine ounces. In estimating the size of the stomach of an infant, not only is its age to be considered, but also its weight; the greater the weight of the infant the greater will be its gastric capacity. After the first six months of life the secretion of gastric juice becomes distinctly more abundant, but during the entire period of infancy free hydrochloric acid is either absent altogether or exists in only very small amounts in the contents of an infant's stomach. In the intestines the villi are numerous and large, even surpassing in size the corresponding structures in the adult, and contain large capillaries. The glands of Lieberkühn are present, but only in small numbers and they are poorly developed. The same is true of Peyer's glands, which do not reach their proper development till the second year of infancy. In a healthy infant the greater part of the food is absorbed from the small intestine. The mucous glands of both stomach and small intestine are more numerous in the infant than in later life, and if unduly stimulated pour forth a copious secretion which readily undergoes acid fermentation and becomes an irritant. The secretion of the pancreas is for the first few months very deficient; three of its ferments are present at birth, viz., trypsin, steapsin, and the milk-curdling ferment, but the amylolytic ferment is quite absent till after the sixth month. Bile is early secreted in considerable quantity, but compared with that of the adult it is defective in organic salts, in cholesterin, in lecithin, and in fat.

The fæces of an infant after the first few days should be of an orange-yellow color, of soft homogeneous consistence, distinctly acid in reaction and not offensive in odor. They are chiefly composed of fats, of fatty and lactic acids in combination with lime, of cholesterin, of intestinal epithelium and mucus, with about three per cent. of the milk ingested which has remained unabsorbed. Meconium is no longer considered to be simply an admixture of bile with intestinal mucus, but is found to contain flat epithelial cells which cannot have originated in the intestinal canal, along with fine hairs and fat globules which have evidently had a cutaneous origin.

GROWTH.—The average weight of the new-born babe is a little over seven pounds, males as a rule weighing a few ounces more than females, but occasionally this average is very much exceeded. During the first two or three days of life a loss in weight of from eight to twelve ounces almost invariably takes place, due partly to the passage of urine and meconium, partly to the disturbance of nutritive processes necessarily associated with its entrance on a new life, and partly to the fact that during these days the infant is not generally able to obtain sufficient nourishment. Townsend, at the Boston Lying-in Hospital, has shown that the infants of primiparæ lose more and are slower to recover their loss than those of multiparæ; large children, however, suffer less loss of weight and recover more quickly than small ones; children which have to be fed artificially do not as a rule regain their original weight before the tenth day. That the loss is to some extent avoidable is indicated by the fact that in the young of mammals which commence to take the dug immediately after birth, increase of weight is immediate and uninterrupted. Any failure of the infant fully to regain this loss by the end of the second week should be regarded as an indication that its nutrition is at fault and special measures should be taken to increase its vitality (Rotch). After the second week there should be a weekly gain in weight of from five to seven ounces for the first five months. After this age growth gradually becomes less rapid. It is generally considered that the initial weight of the infant at birth should be doubled at five months and trebled between thirteen and fourteen months of age. The weight at one year should be doubled at six years and this weight doubled again when the child reaches fourteen years. Weighed from day to day the amount of increase in an infant may be found to vary considerably, even a uniform weekly increase is exceptional. Slight disturbances such as dentition, weaning, improper feeding, or undue excitement may interfere with or even interrupt the regular increment. The weight of an infant carefully and systematically taken is to be regarded as an excellent index of the infant's nutrition, and our most exact guide in determining the suitability and sufficiency of the food supplied. Bowditch has also insisted that actual loss in weight, and sometimes even a failure to gain, is often an early premonitory indication of the onset of constitutional disease.

The average length of the infant at birth is nineteen and three-quarter inches. During the first six months it grows from four to five inches and in the second from three to four. In the second year the gain is from three to five inches, and by the end of the fifth year the child should have doubled its original length. Insufficient nourishment and improper food, especially in rachitic children, retard growth in length. Chronic disease of the brain (idiocy) is apt to give rise to more or less dwarfing. Cretinism, also, in a very marked degree stunts growth. On the other hand an attack of one of the exanthemata appears in some children to accelerate growth.

At birth the circumference of the head much exceeds the circumference of the thorax, but with the rapid development of the lungs the difference is notably diminished during the first few months, and at the end of the first year, notwithstanding the rapid development of the head, the thorax exceeds it. Between six and eight weeks old, the child begins to raise its head and turn it voluntarily toward a bright object and a few weeks later is able to hold it up without support. Not till about the seventh month does it acquire the power of sitting alone, and not till the close of the first year are the lower extremities sufficiently developed to enable the infant to make some effort to stand. Two or three months later it should walk alone. Growth does not always take place uniformly; the head often increases the most rapidly in size, but sometimes the extremities. When growth is too rapid, failure of strength, with anæmia and more or less emaciation, ensues.

About the sixth month dentition generally commences with the eruption of the two lower central incisors and these are followed at varying intervals by the other teeth in successive groups. Every kind of variation may be met with as to the order in which the several groups of teeth appear without any evidence being found either at the time or later of the existence of any pathological condition, mental or otherwise (Rotch). Nevertheless delayed dentition is generally regarded as to some extent an evidence of imperfect nutrition. Merei and Whitehead state that in seventy-nine per cent. of the well-developed, the first teeth appear before the eighth month has passed, while in sixty per cent. of those with imperfect development the first teeth are cut after the eighth month. The following is the formula for their usual appearance as given by Rotch:

Groups.	Time of appearance.
Two central lower incisors	6th to 8th month.
Four upper incisors	8th to 10th month.
Two lateral lower incisors and four first molars	12th to 14th month.
Four canines	18th to 20th month.
Four second molars	28th to 32d month.

During the earlier months of infancy the anterior fontanel remains open, and affords a fair indication by its size of the state of development in the cranial bones, and to some extent of the state of ossification in the body generally; and by the presence or otherwise of any distention in the membrane covering it, of the condition of the brain, whether congested or anæmic. This fontanel is of small size in the new-born, but gradually increases up to the ninth month when its size remains stationary for two or three months, and then it rapidly begins to close (Vogel). Between the fifteenth and eighteenth months in healthy, well-developed children it should become completely ossified.

The Development of the Senses and Mental Faculties in the infant is an interesting study to which in recent years considerable attention has been directed. The first movements of the new-born infant are either purely reflex, like its crying, or impulsive, and due to the unloading, in an objectless manner, of its "inherited provision of motor impulses." Tactile sensation at birth appears to be developed in lips, tongue, eyes, and hands; numerous reflexes of prenatal development also manifest themselves, *e.g.*, respiration, swallowing, winking, coughing, sneezing, etc. With these exceptions sensation, both general and special, is in the early weeks of life very defective. The senses of taste and smell appear to be the first to make distinct and clear impressions on the mind. The new-born can distinguish between bitter and sweet, and the taste and smell of the milk first received makes a permanent impression, so that another is often tried only to be put away. Thus memory and judgment appear to arise first in the domain of these senses.

Hearing and sight are very defective at first, but become afterward of much importance to development. All children are born deaf. Even the strongest do not notice a sharp sound earlier than six hours after birth. More frequently it is some days before we notice the infant starting at a sudden noise. This deafness is due to the fact that the Eustachian tube is closed at birth and is only gradually opened by the acts of breathing and swallowing. Until it is opened the middle ear contains no air, and the tympanum stands too obliquely. After hearing becomes active no organ of sense contributes so much toward mental development. Deaf children are much more backward than are the blind. Toward the end of the third month a child should recognize the direction of a noise and turn toward it. It requires more time, however, before children can distinguish between different sounds. Demme found only two per cent. able to recognize their mother's voice at three and a half months. At six months most babies enjoy being sung to, and are amused by the jingle of rattles.

The infant appears to be able to distinguish light from darkness almost immediately after birth, but that is all, for the movements of the lids and balls are not at first symmetrical. About the sixth week a bright light, if moved slowly, is followed by the eyes, and after the third month we may observe the quick closing of the lids on the approach of an object. By this time also the child should recognize its mother's face. After the sixth month the estimation of size, distance, and color becomes gradually developed, but not till after the third year are all the colors distinguished.

Voluntary grasping is generally noticed very shortly after the third month and with it comes the knowledge of things apart from itself.

Speech is not inborn, but the tendency to it is inherited. At first only vowels are uttered, but after the first few weeks the mental state of the child may be determined to some extent from the different sounds that it makes and its voice gradually becomes modulated to suit its mood. Toward the end of the first year the child begins its first imitation of sound. The progress is more rapid after this, but for a long time expression and gestures are the most important means of communication, and sounds are merely accompaniments. Then one word is used to signify several thoughts, showing the growth of reasoning power. Two or three words are next joined together, and finally complete sentences are formulated. All the disturbances of speech noted in the adult may have their counterpart in the child. In the one the functions are disturbed by disease, in the other the defect is due to insufficient development.

INFANT MORTALITY.—The high rate of mortality in infancy has been referred to and deplored by all writers on the subject. In England, out of 1,000 infants under one year there die annually 141.8; in France, 223.2; in Italy, 273.3 (Farr). These are the mean rates for rural and urban districts; in large cities the rates are higher. In Paris during the four years, 1863–66, the mean annual death rate of infants under one year was 290 per 1,000 living. Eross in a recent article based on statistics obtained from sixteen large European cities, states that about nine per cent. of all children born alive die before the end of the fourth week. In small towns and in the country the rates are much lower than in the cities, but even in these the percentage of deaths occurring in infancy is very large. In this country statistics are not sufficiently defined to enable us to state the exact mortality of the several months and years of infancy. In Boston, with a general death rate not exceeding 24.5 per 1,000, the mean death rate of infants under one year, determined in the four census years 1855, 1865, 1870, and 1875, was 272.7 per 1,000 infants living, while for children under five it was 95.6. These rates are still true for many of our large cities, but in others it is probable that a great diminution in them would be found to have taken place in recent years. Wende (*Pediatrics*, vol. ix., 1900, p. 103) states that in 1890 out of a total of 5,024 deaths in Buffalo, N. Y., 2,305 were under five years of age; but in 1898, owing to a careful inspection of the milk supplied to infants, and to greater care in the feeding of it, out of a total of 4,533 deaths, only 1,570 deaths of infants under five years were recorded.

The high mortality rate in early infancy demands an earnest consideration of the causes that may give rise to it and an effort on the part of every physician to reduce it. Unfortunately some of the causes contributing to it appear at present to be unavoidable. The great and important changes which take place in the organism with the completion of birth, and the rapid development which afterward ensues, are both fraught with special dangers, even to those naturally healthy. In many instances, however, we have the added weakness involved in hereditary disease; syphilis and tuberculosis in the parent necessarily entail an enfeebled offspring unless active preventive measures be taken. Even when we have no distinct diathetic disease to deal with, general debility and many chronic affections in the mother affect the vitality of the offspring unfavorably and render it more liable to succumb to disease. Dr. Curtis estimated that from ten to fifteen per cent. of all deaths under five years must be assigned to this class of hereditary causes. Ashby, in an analysis of the causes of death in two thousand infants under two years of age, estimates that congenital syphilis was the active agent in ten per cent. Acute zymotic disease also plays an important rôle; pertussis has its maximum fatality during the first year of life and measles in the second, while scarlet fever does not reach its maximum fatality till the third and fourth years. Ashby in the analysis above quoted states that pertussis was the cause of death in twelve per cent. and measles in nine per cent. of his cases. Unfavorable hygienic surroundings may increase largely the mortality of this class of diseases by weakening the vitality of the infant and perhaps by increasing the virulence of the poison itself, while strict isolation and thorough disinfection will undoubtedly lessen the frequency and diminish the mortality from this source.

Diseases of the alimentary tract contribute largely to this high death rate. Jacobi has estimated that the deaths from this cause alone in the first year of life amount to nearly forty-one per cent. of the total number which occur at this period of life. In the second year the mortality, although large, is not quite so great. This class of disease must be regarded as resulting almost entirely from defective knowledge and care in the feeding and hygienic surroundings of the infant, and therefore in great part preventible. Inflammation of the respiratory organs, principally bronchitis and pneumonia, is also another important cause of this high rate of mortality. Dr. Farr states that in England this class of diseases is the cause of nearly one-sixth of all the deaths under five. According to Jacobi twenty-one per cent. of all the deaths in the first year of life are due to this cause, and about thirty-six per cent. of the deaths in the second year. In the majority of the cases in this class, imperfect ventilation of living rooms, and undue exposure to wet and cold with insufficient covering to chest and extremities, conduce greatly to this result. It is surely not too much to hope that with the rapid diffusion of more exact knowledge of the important principles of hygiene and infant feeding, this excessive mortality in infancy may be greatly reduced.

INFANT HYGIENE.—*Feeding.*—As soon as the mother has to some extent recovered from the exhaustion of labor, the infant should be applied to the breast. Although the full supply of milk is not established until the second or third day, yet, as a rule, sufficient will be obtained to satisfy the infant; when it is very feeble, however, artificial feeding with a weak sterile cream mixture may be advisable. At this early period the infant does not require much and a frequent application to the breast is unnecessary. Should the influx of milk be delayed and the infant be fretful, feeding with some substitute milk may be deemed advisable. For the first month it is difficult to obtain regularity in nursing, but the importance of regular feeding should be impressed on the mother, and she should be told that crying and fretting during the intervals are in general due not to hunger, but to colic, which may be aggravated by irregular nursing. After the second month an interval of at least two hours between two successive nursings should be insisted on for the day; during the night this should be lengthened to three or four. As the child grows older its stomach becomes capable of taking larger quantities at a time, and the intervals should accordingly be gradually lengthened to four hours. In some cases the breast milk of the mother does not agree with the infant and gives rise to more or less pronounced symptoms of indigestion associated with much fretfulness, sleeplessness, and either an actual loss of, or a failure to gain in weight. This condition of the milk is sometimes due to over-anxiety, insufficient sleep, an improper dietary, or irregular habits on the part of the mother, and may be remedied by securing for her a correct dietary, regular outdoor exercise, sufficient sleep and freedom from undue worry and excitement. In a few instances, however, the fault appears to be irremediable, and artificial feeding with a properly constituted food must be attempted. (See article *Infants, Artificial Feeding of.*)

In estimating the suitability of any food to an infant's requirements the important test is the weekly increase in weight. If the food is digestible, and sufficient in amount for its wants, the infant should be free from colic, happy in disposition, should sleep quietly, and gain regularly in weight. No fixed rule can be stated as to the proper time to allow artificial food in connection with breast milk. While robust mothers, with an abundant supply of milk, can easily satisfy their infants up to the age of twelve or fifteen months, many begin to feel the drain upon them by the second or third. In others, the milk, though abundant, fails to satisfy and sufficiently nourish the child, and must be early supplemented by artificial food.

Bathing.—The first bath of the infant should be given in a warm room, free from draughts, and in water of a temperature of 96° F. The infant should be dried beneath some warm flannel covering. In general, nurses are not sufficiently alive to the necessity of preventing undue chilling of the surface. From the fifth to the ninth day the navel string becomes detached, and not till that occurs is a second general bath advisable. After that the bath should be given daily in water at a temperature of about 92° F. This temperature, after the age of eight or nine months, may be lowered carefully to 90° or 85°, according to the strength of the infant and the vigor of its reaction. Too prolonged chilling of the surface during bathing and dressing is the frequent beginning of catarrhs of all sorts.

Clothing.—In the dressing of the new-born care should be taken that there is no injurious dragging on the navel, that the usual abdominal band is not applied so tightly as to interfere with respiration or digestion, and that sufficient warmth be secured for the extremities. Later on, caution should be enjoined that none of the clothing press unduly on either chest or abdomen—all should hang loosely from the shoulders; neck bands should not be tight, and the extremities should always be efficiently and warmly covered. No sudden change in the amount or character of the clothing is, on any account, to be permitted. Special care is also to be given to the shoes. The leather should be pliable, and the shoes made broad and loose about the toes, so as to allow freedom for movement and growth.

Sleeping.—For the first few weeks of its life an infant should sleep eighteen hours out of the twenty-four. As it grows older, it gradually requires less. A fretful and wakeful baby is ailing in some way, and the cause of its fretfulness should be found out and remedied. When possible, the nursery should be large and well ventilated. For the first few days of infant life it may be desirable that the room in which it is kept should be somewhat darkened, but after that fresh air and sunlight should never be excluded. At the same time draughts and rapid changes of temperature are fraught with much danger.

Exercise is important, but the manner of it is equally so. No infant should be carried about upright until it is able to raise its head and rotate it easily; nor should it be encouraged to walk or stand till nearly a year old, and if there be any tendency to rachitis this must be postponed still later. After an infant is three months old—a little later, in the winter season—it should be "short-coated," and the fullest liberty given to its arms and legs. It should be encouraged to lie on its back in its crib with loose clothes and enjoy, as it will do, the liberty of kicking. Every day it should be taken out regularly during the more suitable portion of the day, unless the weather be blustery. When it is sufficiently old, walking forms a pleasant exercise, but it should never be carried to the extent of much fatigue.

Weaning should, if possible, be effected gradually, and the digestive organs should be accustomed to some suitable artificial food before lactation is altogether stopped. Abrupt changes in its food try an infant's digestion, and frequently upset it. In selecting the time to make the alteration, attention should be given to the following points: 1. An interval between the eruption of the several sets of teeth should, if possible, be chosen, as we sometimes notice at these times irritation of the nervous system with hyperæmia and increased peristalsis of the alimentary canal. 2. It is never desirable to take the breast from an infant while it is sick or recovering from sickness, unless it is manifest that the milk of the mother is injurious. Even an inadequate supply will often be all-important for the nourishment of such an one (Busey). 3. Regard must be paid to the season of the year. Any change during the hot months is very undesirable.

In the EXAMINATION of infants much tact and observation are necessary. All appearance of abruptness is to be avoided; no harshness in voice or manner is allowable; the physician's hands must be warm; and a full supply of patience must ever be ready to be exercised if demanded. If the infant be asleep on the physician's arrival, it should on no account be awakened until he has seen its decubitus, counted its pulse and respirations, and noted their character, and made such other superficial examinations as are possible without disturbing it. The pulse and respirations in an infant just awakened are always extremely rapid. With regard to its decubitus, a healthy young infant in sleeping generally assumes the position he is supposed to have had *in utero.* An older infant, even if lying on its back, should incline its head to one side or the other, so that its cheek comes in contact with the pillow. If it be found with closed eyes and face directed straight upward, it is probably suffering from serious disease. If it be lying with its head retracted, cranial disease should be thought of. If it sleep on its belly, or resting on elbows and knees, it is probably suffering from abdominal discomfort. Healthy children should sleep quietly. Much tossing, any twitching of the muscles, or screaming and talking in sleep, indicate feverishness or digestive derangement.

Much may be learned from the character of the child's cry. Unappeasable screaming, without any other symptom, often results from earache. The temperature should always be taken with a sensitive thermometer, preferably in the rectum; if not convenient there, in the groin. The armpit is not so good, as infants object to the necessary restraint of the arm. In many abdominal troubles the skin and extremities may be quite cool, yet the thermometer in the rectum show a temperature of 104° or 105°. The respirations, if practicable, should always be counted. At the first examination we should always insist on having the infant stripped, otherwise no thorough examination can be made. Care should at the same time be taken that the infant be not chilled by a too prolonged examination. Passing downward, we note: (1) shape of child's head and state of fontanel; (2)

shape of chest, character of the breathing, whether there be any retraction of chest walls or intercostal spaces. With warm hands palpation should be made, and the expansion, and also the presence, if any, of rhonchal fremitus should be noted; (3) shape of abdomen, whether protuberant or retracted, whether the walls are tense or lax. Gentle pressure may be made by the hand, and any tenderness of the abdomen or enlargement of liver or spleen detected; (4) condition of the lymphatic glands.

In addition, the color and elasticity of the skin and the general nourishment of the tissues should be observed at this time. In auscultating the chest, the infant should be placed on the left arm of the nurse, leaning over her left shoulder, with its arms around her neck. In this way only are the muscles of the back equally relaxed and correct results obtained. Percussion should always be gentle. Immediate auscultation never gives the exact results obtained by the use of the stethoscope, but any painful pressure by the instrument must be carefully avoided. In infants, symptoms of disease are more frequently found at the back than at the front, and at the base rather than at the apex. Nevertheless, no part should be omitted in the examination. Inspection of the mouth and fauces should always be left to the last, as giving rise to more or less resistance. To effect this the infant should be seated on the nurse's lap before a bright window. Sometimes with a little gentle pressure on the chin the mouth is opened and the tongue seen. To examine the fauces requires the use of a depressor, for which nothing is better than the smooth handle of a spoon. This can always be slipped in behind the teeth and over the tongue to its base. When the pharynx is reached the mouth involuntarily opens, and, if the physician be on the alert, a good view of the fauces is obtained. Lastly, the secretions should be examined, if in any way at fault. Trouble is sometimes experienced in obtaining the urine. If necessary, a small silver catheter may be passed and a sample drawn off.

In making our diagnosis and prognosis in infancy, the following points must always be remembered as modifying disease at this period:

1. The wide diffusion of symptoms met with at the onset of an acute attack.
2. The severity of the initial symptoms often bear no proportion to the gravity of the local lesion.
3. The extremely rapid rise and fall in the temperature of the body frequently observed.
4. The rapidity with which functional mischief may pass into organic.
5. The extent to which local disease is modified by certain diatheses.

For an account of the special diseases to which the infant and new-born are liable, the reader is referred to the separate articles on these diseases.

Alexander D. Blackader.

The following papers and treatises have been referred to and made use of:

Thomas Rotch: Pediatrics, 1901.
L. Emmett Holt. Diseases of Infancy and Childhood, 1897.
Colton: Lessons on Anatomy, Physiology and Hygiene of Infancy and Childhood, Chicago, 1900.
Alfred Vogel: A Practical Treatise on Disease in Children; translated by H. Raphael, 1885.
Fred. Treves: The Anatomy of the Intestinal Canal and Peritoneum in Man, London, 1885.
A. Jacobi: Infant Hygiene. Buck's Hygiene and Public Health, 1879.
Thomas B. Curtis: Infant Mortality. Buck's Hygiene and Public Health, 1879.
A. Jacobi: Anæmia in Infancy and Early Childhood. Arch. of Medicine, vol. v., No. 1, New York, G. P. Putnam.

INFANTS, ARTIFICIAL FEEDING OF.—When for any reason the infant is deprived of its mother's milk, its natural and most perfect food, the necessity of supplying it with nourishment from some other source is forced upon us. This may best be done by means of a healthy, efficient wet-nurse, if such can be obtained; but this is always a difficult matter. Very seldom can one be found who fulfils all the requirements demanded by the physician, and who is willing to submit to the careful dietary and regular mode of life necessary to insure a wholesome and even supply of breast milk to the foster child. In the great majority of cases, therefore, we have to find some artificial nutriment which shall fulfil the important conditions of being easily digested by the infant and at the same time of supplying in due amounts all the elements required for nutrition.

Nitrogenous material it must have to provide for the wants of the growing tissues; without a sufficient quantity of this element in the food, growth and development will be defective. Carbohydrates must also be present. Not only are they essential to nutrition, but they are also necessary for the production of heat in a being whose muscular activity is comparatively slight, yet in whom the activity of the vital processes would be much impaired were the body heat lowered in any degree. These carbohydrates must be in a condition easily assimilated, and it is to be remembered that during the early months of life no provision is made by nature for the digestion of starch; they must, therefore, be supplied in the form of some sugar, and of the various sugars milk-sugar appears for the infant to be the most assimilable. Fats appear to be closely associated with new cellular growth, and must be supplied in a state of fine emulsion. The food must also contain a due amount of mineral matter, calcium phosphate for the hardening bone, and sodium chloride and iron for the blood, daily increasing in amount. Salines are also undoubtedly of much service in the vital processes of digestion, absorption and nutrition; processes for which water is demanded in larger amounts than required by the more adult constitution.

To supply a food suitable in all these respects to the wants of the infant organism, and yet easily digested and assimilated by the imperfectly developed alimentary tract of the infant, is a problem demanding much thought and care. Its importance will be appreciated when we consider the disastrous results which frequently follow attempts made in thoughtlessness and ignorance to hand-feed infants. The enormous death rate which in all countries occurs among those deprived in early days of maternal milk is appalling, while among those that survive, poor health, defective nutrition, and stunted growth plainly attest the defective nourishment supplied. As a recent writer says, it is proper or improper nutriment which makes or mars the perfection of the coming generations.

The problem, although at all times demanding careful thought, is one of very varying difficulty. If the powers of digestion are naturally strong, and especially if the infant has received the advantage of maternal nursing until the gastric and intestinal secretions have become to some degree developed. the task of supplying a suitable food may be a comparatively easy one. But if the infant inherit a weak constitution with feeble powers of digestion and assimilation, still worse, if it must be bottle-fed from its birth, much difficulty will be experienced; our difficulties are still further increased during the hot season and under the unsanitary influences associated with city life. It is only within the last few years that advancing knowledge has enabled us to cope, for the most part successfully, with these various difficulties, and it must be acknowledged that for the greater part of this advance we are indebted to American physicians.

In the preparation of a substitute food for infants, it must be our aim to copy as closely as possible in all particulars the food which nature supplies. The substitute food must resemble maternal milk in the elements entering into its composition, in the percentage of them present in the food, in its freedom from the presence of noxious micro-organisms, and in the fact that it is an animal food. To enable us to attain this result, many careful analyses have been made to find out the exact composition of mother's milk.

Rotch gives us the following as a summary of several of the more recent analyses of human milk:

AVERAGE HUMAN MILK. (Rotch.)

Reaction	Amphoteric or slightly alkaline.
Specific gravity	1.028 to 1.034.
Water	87 to 88 per cent.
Total solids	12 to 13 per cent.
Fats	3 to 4 per cent.
Milk-sugar	6 to 7 per cent.
Proteids	1 to 2 per cent.
Total mineral matter	.1 to .2 per cent.

As an indication of the differences which may exist in the breast milk of different women, the following analyses, made by Harrington and quoted by Rotch, are interesting:

HUMAN BREAST-MILK ANALYSES.

(Mothers Healthy and Infants Digesting Well and Gaining Weight.)

	I.	II.	III.	IV.
Fat	5.16	4.37	3.28	3.16
Milk-sugar	5.68	6.30	5.70	7.20
Proteids	4.14	3.27	1.08	1.65
Mineral matter	.17	.16	.20	.21
Total solids	15.15	14.10	10.80	12.22
Water	84.85	85.90	89.20	87.78

In connection with these analyses it is to be noted that, although the several infants digested and throve well on their own mother's milk, when supplied with milk from another mother colic and disturbed digestion frequently resulted. Breast milk may also vary according to the period of lactation at which it is drawn. Baginsky quotes the following as the result of numerous analyses made by Pfeiffer:

Period of lactation.	8th day.	65th day.	371st day.
Water	89.62	89.72	87.72
Total albuminoids	2.365	1.496	1.552
Casein	1.665	.844	.718
Albumen	.108	.228	.183
Undetermined albuminoids	.592	.424	.651
Fat	3.345	1.827	3.984
Sugar	3.274	6.22	6.088
Salts	.446	.180	.126

It is evident from these analyses that we have to deal with a fluid which, while containing all the elements necessary for the perfect nutrition of the growing infant, contains them in quantities which may vary considerably in each individual case, and to some extent from time to time. Of its several constituents the proteids and the fats are the most variable in their amounts, while the sugar in all is comparatively constant. This perhaps is only what we should expect from what we know of the secretion of milk, and considering how liable mothers are to the influences of worry, overexcitement, and disturbed sleep. In the majority of cases infants digest and assimilate their own mother's milk easily, but in a few instances, in which the mother's milk has contained a high percentage of proteids with a low percentage of fats, it has proved indigestible and has given rise to colic and much disturbance of the digestive tract. We may, therefore, infer that more or less variation in the composition of our substitute food will be necessary in many cases to secure a product that will suit the digestive idiosyncrasies of the infant as an individual and yet be efficient as a source of nutriment to its growing tissues.

ANALYSES OF THE MILK OF VARIOUS ANIMALS. (After König.)

	Cow.	Goat.	Ewe.	Mare.	Ass.
Water	87.41	86.91	81.63	90.71	91.40
Caseinogen	3.01	2.87	4.09	1.24	1.23
Lactalbumin	.75	1.19	1.42	.75	
Fat	3.66	4.09	5.83	1.17	3.01
Sugar	4.92	4.45	4.86	5.70	6.93
Mineral matter	.70	.96	.73	.37	.45

At the outset of our endeavors to prepare such a food we naturally turn to the milk of other mammals, and of these the milk of the cow, goat, ewe, ass, and mare have been by various writers recommended for this purpose. Careful analyses have been made of these various milks, with the results shown in the last preceding table.

It is evident that the milk of the ass and mare approaches more nearly that of the human being than does that of the cow, but as it is impossible to obtain from these animals a supply in any way adequate to our wants, they may be dismissed from our present consideration. Goats' milk, although more frequently available, possesses no advantage over cows' milk. The quantity of casein in it is large, and its peculiar odor is often very objectionable. Cows' milk, on the other hand, has many advantages; it is plentiful and cheap, and can with due care be obtained fresh and pure. The following analyses of the two milks, as given by Rotch, shows us how closely they resemble one another in composition:

	Cows' Per cent.	Woman's (directly from breast). Per cent.
Reaction	Slightly acid.	Amphoteric, generally alkaline.
Water	86–87	87–88
Mineral matter	.70	.20
Total solids	14–13	13–12
Fats	4.00	4.00
Milk-sugar	4.50	7.00
Proteids	4.00	1.5–2
Caseinogen	2.88	.59
Lactalbumin	.53	1.23

Although on comparing these two tables we see much similarity between the two fluids, nevertheless important points of difference may be noted. While human milk is almost always alkaline and remains so for many hours, the reaction of cows' milk is acid, owing partly to the presence in it of potassium biphosphate, and partly to the formation of small quantities of lactic acid; especially is this the case when the cow is stall-fed or the milk a few hours old. Our knowledge does not as yet permit us to recognize any difference between the fats in the two milks. The milk-sugar is notably deficient in cows' as compared with human milk. The mineral matter is more abundant in cows' milk. An analysis of the saline ingredients in the two milks shows that the potassium salts are in larger proportion in breast milk, while the lime salts are more abundant in cows' milk. Cows' milk also contains more phosphoric acid, less chlorine, less iron, and less sulphur. These differences, however, may be regarded as comparatively unimportant. The most important practical difference exists in the proteids, of which we notice that in cows' milk the greater part may be readily coagulated, forming tough and dense curds, while in human milk the coagulable proteids exist only in small amount. König's analysis shows that, while in human milk the caseinogen forms one-third and the lactalbumin two-thirds of the proteids, in cows' milk the caseinogen forms four-fifths and the lactalbumin only one-fifth. As a result of this difference, it is noticed that on coagulation of the proteids of human milk by acids or rennet the curds form slowly and are small and flocculent, whereas in cows' milk they form comparatively rapidly and are large and tenacious. Similar results are observed when the two milks are acted upon by artificial gastric juice in a test tube; the proteids in woman's milk are precipitated slowly and imperfectly and are easily redissolved in excess of the juice, while the proteids of cows' milk are precipitated in large masses which are redissolved only with difficulty.

Another important difference between the two milks still remains. While breast milk is always practically sterile, commercial cows' milk invariably contains many bacteria, from one hundred thousand to several million in each cubic centimetre, and if old it also contains the toxins evolved by their actions. It is therefore extremely important that milk to be employed in the feeding of infants should be obtained from healthy, vigorous animals, cleanly kept under the best hygienic conditions, and carefully fed and watered. The milking should be done with careful precautions to avoid contamination by impurities (see article *Milk*). The milk should at once be cooled and aërated and delivered to the consumer with as little delay as possible; prolonged transportation is to be avoided. Milk may acquire noxious properties and be rendered dangerous as a food, especially for infants, by (1) poisonous weeds taken with the food; (2) by diseased conditions in the cow; (3) by contamination with pathogenic organisms communicated during either milking, or storing, or transportation. Whenever the temperature of milk is allowed to rise above 7° C. (45° F.), it becomes an excellent culture medium for the growth and development of the many forms of bacteria which, even with our most careful precautions, are always present to a greater or less extent. Milk containing micro-organisms in excess of ten thousand per cubic centimetre must be regarded as unfit for infant feeding.

Cows' milk also varies considerably in its percentages according to the special breed supplying it, according to the character of the food on which they are fed, and the amount of exercise permitted. It is therefore desirable that before employing cows' milk for the feeding of delicate infants, for whom fine adjustments may be necessary, an analysis of the milk supplied by the herd should be obtained. Afterward an effort should be made to maintain uniformity by careful regulation of the food.

Obtained with the above precautions, we have in pure cows' milk a food which, compared with breast milk, contains an equal amount of fat, an excess of indigestible proteids, an insufficiency of sugar, and an excess of saline matter; our efforts must therefore be directed so to modify its composition and the character of its proteids as to render it suitable and digestible by the young infant.

Many plans have at various times been recommended. Simple dilution lessens the amount of the proteids, and to a slight extent renders the curd formed by them less dense. It reduces, however, the fats and sugars much below the amount demanded by the infant organism. Keller has also shown us that with a low percentage of carbohydrates in the food there is a very low retention percentage of nitrogen in the system, and general nutrition is defective. Mere dilution, therefore, is not to be commended.

Lehmann many years ago pointed out the effect of the addition of an alkali in rendering the curd less dense. He writes that human milk when acid yields a much thicker coagulum than when alkaline, and cows' milk when alkaline a much looser coagulum than when acid. We also know that casein is precipitated from its solutions by acids, while its precipitation is retarded by the presence of neutral salts. It is, therefore, always desirable to have the acidity of cows' milk well neutralized by an alkali, and for this purpose either lime water or sodium bicarbonate may be employed. It is to be remembered, however, that milk, when recently drawn from pasture-fed cows, is much less acid than the milk of cows stall-fed on dry fodder and grain. Milk also increases in its acidity on standing, owing to the conversion of some of the milk-sugar into lactic acid by the numerous lactic-acid-producing bacteria always present in milk. Harrington ascertained by experiment that ordinary milk, twenty-four hours old, required the addition of one-sixteenth of its volume of lime water to make its alkalinity correspond with that of breast milk. The addition of one-eighth of its volume of lime water rendered it strongly alkaline. Fresh milk from cows on pasture required a much smaller quantity. When constipation is present in the infant, sodium bicarbonate may be used in place of lime water to the extent of from five to ten grains to the pint of milk.

Another plan, frequently recommended as preventing the formation of firm, tough curds is to dilute the milk with a thin gruel, which by its physical consistence is able to diminish the density of the coagulum. This method is an old one, as we read that Van Swieten, in the fifteenth century, used decoctions of wheat or barley for this purpose; but its utility has of late years been very strongly urged by Dr. Jacobi and Dr. Chapin. That it has a distinct value has also been proved by Professor Leeds, who, in a series of careful experiments, showed that the coagulum which forms in a thin gruel encloses much material which, by honeycombing the curd, acts as an attenuant. Coagulation also takes place more slowly—a very positive advantage, as it affords the digestive fluids a better opportunity for action. Many substances have been used for this purpose. Dr. Jacobi recommends well-boiled decoctions of barley or oatmeal. He says: "I have always preferred barley when an article for steady diet was to be recommended, for the reason that oatmeal, on account of its containing fat and mucin, tends to relax the intestines more than barley meal. Otherwise the chemical composition of both is so nearly alike that it would make but little difference upon which the choice would fall. . . . In the case of very small children, the whole barley corns ground for the purpose should be employed, on account of the proteins being mostly contained just inside and very near to the husk." When the smaller pearl-barley is used, Dr. Jacobi thinks that much of the gluten is lost with the husk. Gum arabic and gelatin may also be employed in the case of very young infants.

Dr. S. C. Busey urged the advantage occasionally obtained by substituting rice water, prepared in a similar way, for the barley gruel, and says that he has often witnessed its beneficial effects in cases of diarrhœa and vomiting.

The disadvantage of all such diluents, however, for young infants, is that they introduce a material quite foreign to milk, and one with which their digestive powers are unfit to grapple until their salivary and pancreatic secretions become somewhat developed. For such, therefore, the addition of a gruel to milk has no nutritive value, but serves only as an attenuant of the casein. Dr. Jacobi, however, considers that a small amount of starch may be digested at the very earliest age. It is nevertheless important that in all cases the percentage of starchy matter should be small, and that it should be very thoroughly cooked. Recently Chapin has strongly advocated the use of a gruel made from wheat, barley, or oatmeal, the starch of which has been predigested or dextrinized by the addition of some form of diastase. His directions are as follows: "A heaping tablespoonful of flour made from one of these cereals is boiled with a pint and a half of water for fifteen minutes. It is then removed from the stove and set in cold water till cooled to about 120° F., when a teaspoonful of some good preparation of diastase is added; this dextrinizes the starches and renders the gruel thin, watery, and easily assimilated by the infant, though it still remains an efficient attenuant of the curd."

In addition to these methods of preventing the firm coagulation of the casein, it is always practicable to predigest the proteids of the milk by means of one of the numerous preparations of pancreas, and thus to do away more or less completely with the formation of the curd. A peptogenic milk powder has also been prepared, containing pancreatin and bicarbonate of soda, along with milk-sugar. When the food is wanted the powder is added to a mixture of milk, cream, and water, and the whole is kept at blood heat for some minutes. When properly prepared the resulting milk should closely resemble mother's milk in the reaction of its proteids and its composition.

In practical use, however, predigestion of milk does not appear to have given as excellent results as was at first anticipated. It is a method that may be employed occasionally with benefit in cases of severe exhaustion accompanying or following acute disease, and in some forms of gastric disorder associated with a temporary inability to digest the proteids in milk. The degree to which the predigestion must be carried at first will depend on the power of proteid digestion present in the infant, but in all cases as soon as possible the time of predigesting the milk and therefore the amount of peptonization it undergoes should gradually be lessened; predigestion of food for any lengthened period appears to be quite opposed to the teachings of physiology.

In all these methods, however, with the necessary dilution of the milk, the quantity of fats and sugar falls far below the requirements of the growing infant organism and requires to be increased. In reference to the deficiency in the fat, Dr. Jacobi puts in a strong plea against allowing any excess to be present in our mixtures. He says that the infant does not digest all the fat contained even in its mother's milk, and we ought not therefore to increase the amount of the indigestible ingesta by adding to them. In opposition to this, Dr. Rotch very pertinently remarks: "We have no right to conclude from the fact that a certain amount of surplus fat is found in the napkins, that only a small per cent. is sufficient for nutrition. It is more probable that nature introduces a certain percentage of fat in human milk with a purpose which can only be accomplished by that percentage,and it will be an error on our part not to conform to our standard." My own experience confirms that of many others, that average infants can digest from two to four and one-half per cent. of fat; more than this is liable to give rise to gastric disturbance, and may induce vomiting or diarrhœa; a deficiency in the fat, however, will interfere very distinctly with the infant's nutrition. Biedert also says that while remarkably small amounts of proteid may be sufficient for the good development of infants during the first few weeks of life, an increase in the amount of fat considerably above what is contained in dilute cows' milk spares albumin, renders digestion easier, and increases the growth of the child.

To make good the deficiency in the fat, we have to rely on creams of known strength. The only serious drawback to its employment is the difficulty of obtaining it fresh and sterile. Freeman has told us that when milk is set the great majority of the bacteria rise with the cream, leaving the separated milk comparatively free. In the food of infants cream more than twelve hours old should not be employed.

In correcting the deficiency of the sugar the majority of pediatrists prefer to use milk-sugar, the form found in the milk of all mammals. Jacobi, however, prefers cane sugar, considering that the identity of the lactose in human and cows' milk is very doubtful and that the commercial milk-sugar is often very impure. He also thinks that as milk-sugar readily undergoes the lactic-acid fermentation, any excess of it tends to increase the elimination of calcium phosphate and may thus favor the development of rickets. On the other hand, Vaughan considers that milk sugar is more readily assimilated by infants, and Escherich states that milk-sugar when acted on by the Bacillus lactis aerogenes develops lactic acid, which tends to prevent the development of many noxious forms of bacteria. In general, milk-sugar would appear the preferable form to employ, but should it at any time give rise to symptoms of indigestion, or should pure milk-sugar be difficult to obtain, cane sugar may be employed, but in smaller quantities, owing to its greater sweetness.

Until very recently, in our attempts to modify cows' milk by any of the above methods, we spoke and thought in measures of milk, cream, and sugar, without a very clear idea of the exact percentages in which the elemental constituents of the milk—the fat, the caseinogen, the lactalbumin, and the sugar—were present in our mixtures. A few years ago Dr. Rotch introduced the method and emphasized the value of thinking, working, and speaking entirely on the percentage plan, and of making our modifications from a cream containing a known and definite percentage of fat, and from a milk containing a known and definite percentage of proteids, fat, and sugar. By this plan scientific accuracy was substituted in our modifications for much indefiniteness, and we were not only enabled to prepare a food which we could feel sure exactly resembled breast milk in its physical characters and chemical composition, but also to vary the percentage of the several constituents so as to render it suitable to the varying wants of the different individual infants. On this subject Dr. Rotch says: "While in quite a number of cases rather gross changes in the percentages of the different elements of the milk may be sufficient for the range of the individual digestion and for the nutrition of the special case, yet in a large number of infants whose vitality is low and digestive powers feeble, good results can only be obtained by gradual and minute changes in the percentage combinations of the milk elements."

For such we must have the power of making use of modifications as precise as our knowledge at the present time renders possible. Even slight changes in the percentages of the fat, the sugar, and the proteids are of real value in the management of the digestion and nutrition of the infant.

The substitute food must be adapted, not only to the infant's stage of development, but also to its individual capability of digesting the several elements of its food. To enable us to obtain these varying combinations of the milk elements and to have them regularly and exactly supplied to our patients, Dr. Rotch originated *milk laboratories*, which have been established in many of our large cities, equipped with special machinery and placed under the management of men specially trained for the work. The milk employed in these laboratories is obtained with the strictest precautions to insure its absolute cleanliness, from vigorous cows of a carefully selected breed. The feeding and housing of these cows are under careful supervision, and are so arranged that milk of a known and almost uniform composition is obtained. From this milk, by means of the centrifugal separator, the fat is separated and a cream of uniform percentage obtained. The milk remaining is almost fat-free, and is found by frequent analysis to contain a fairly uniform percentage of proteids, milk-sugar, and mineral matter. It is now a simple matter to dilute, with distilled water, either the cream or fat-free milk, so as to obtain the requisite amount of proteid; milk-sugar is added to make up the defective percentage in that element, and cream supplies the exact quantity of fat. With a knowledge of the exact percentages in the cream and fat-free milk, a simple calculation suffices to obtain the formula within certain limits for dispensing whatever percentage of the elements the physician may prescribe. These limits are as follows:

Fat from	.03 to 36.00
Sugar	.87 to 20.00
Proteids	.22 to 4.00

The amount of mineral matter may be disregarded, as the dilution required by the proteid practically makes a sufficient reduction in its amount.

The milk thus modified may be sterilized, at the temperature deemed necessary by the physician, and is then placed in bottles, each containing the amount ordered for one feeding of the infant; the total number of feedings for the day, securely packed in a small basket, are delivered each morning to the consumer.

The following is an illustration of the method in which this modified milk may be ordered by the physician:

Fat	3.00	No. of feedings	9
Milk-sugar	7.00	Amount at each feeding	75 c.c. (2½ oz.)
Albuminoids—			
Caseinogen	.25	Infant's age	3 weeks.
Lactalbumin	.75	Infant's weight.	9 pounds.
Mineral matter	...	Alkalinity	5 per cent.
		Pasteurize at	155° F.

Although this is a very great advance on our previous crude methods of modifying cows' milk, nevertheless many instances occur in which even the small amount of casein present in the diluted milk overtaxes the feeble digestive powers of the infant. In these Rotch has recommended that the amount of proteids be reduced at the first to a minimum, and then gradually, as the infant's digestion becomes stronger, their amount may be increased until the quantity necessary for perfect nutrition is attained. Thus, beginning with a proteid percentage of 0.25, he advises that it be slowly increased up to 1 and afterward 1.50. Many physicians, however, experience much difficulty in making this increase as rapidly as the demands of nutrition appear to require, and a recourse has been had to the addition of one of the cereal gruels, which in many instances appear to render the casein more digestible.

Very recently Dr. Rotch has proposed to get rid of the caseinogen, in young infants such a frequent source of trouble, by the use of a whey obtained from fresh cow's milk by the use of rennet. Thus prepared, whey contains all the lactalbumin, sugar, and mineral matter, but none of the caseinogen and almost none of the fat. Its average composition, as compared with that of whole milk, is as follows:

	Whole milk.	Whey.
Fat	4.00	0.32
Sugar	4.50	4.79
Proteids	4.00	.85

Many years ago a similar plan was recommended by Professor Frankland, who employed fresh calf's rennet. Dr. Rotch's directions for its preparation are as follows: For each pint of whey required take one quart of whole fresh milk, or fat-free milk, heated to 37.7° C., and add 8 c.c. of essence of pepsin or an equivalent of one of the liquid preparations of rennet. This will precipitate the casein in the form of curds, which are afterward to be broken up with a fork; the fluid remaining is then strained through several thicknesses of boiled cheese cloth and slowly cooled to a temperature of 10° C. It must be kept on ice till required. If the whey is to be mixed with cream, it must first be heated to 65.5° C., in order to kill the rennet enzyme. Whey mixtures should not be heated above 68.3° C., if one wishes to keep safely under the coagulation point of the lactalbumin. With whey as a basis to which cream and milk-sugar in requisite amounts may be added, a modified milk may be prepared which will exactly correspond in its percentages and reactions to that of breast milk. This modification will be found of great value during the early months of infancy, while the digestive powers of the infant are still feeble.

Should whey not be employed, the amount of the proteid element must for some weeks be kept at a minimum and only gradually increased. A slight increase should be arranged for, however, every week or fortnight. Northrup insists that by the ninth month infants should be able to digest full milk, and considers that the slow dentition, anæmia, and loss of weight frequently observed in the later months of lactation are attributable to an insufficient amount of the proteids.

While milk laboratories are not only a great convenience to the physician in the preparation of these various combinations of percentages, but also of value in permitting such combinations to be made with greater exactness than by any method of home modification, nevertheless the advantages of a milk laboratory are not everywhere to be obtained, and in the opinion of many physicians modifications of milk can be carried out at home with sufficient exactness to fulfil the wants of the great majority of infants. To succeed, however, the physician must be capable of giving exact instructions as to the details of the process.

In undertaking home modification it is extremely important to secure a supply of good fresh milk, and one in which the percentage of the fat is known and maintained by careful feeding at a fairly uniform amount. It is to be remembered that the amounts of fat will vary very much according to the particular breed of cows supplying the milk. In an average mixed herd the fat generally amounts to about 4 per cent.; in a herd of Jersey or Alderney cattle it may amount to 5 or 6 per cent. On the other hand, if during the winter season the cows be poorly fed and housed, the fat may not much exceed 2 per cent. Cream obtained by a centrifugal separator contains from 20 to 30 per cent. of fat, together with a slightly lessened percentage of proteids and milk-sugar, and may be employed with advantage in the preparation of mixtures in which a very small amount of proteid is required. For general use, however, the most convenient way of obtaining a cream or superfatted milk, from which to prepare our percentages, is to take advantage of the deep-setting process, *i.e.*, to allow fresh milk to stand in a tall glass jar on ice for some hours. After standing for twelve hours the cream will have almost all separated and will contain about 16 per cent. of fat. If it stand only six hours, the upper fourth will contain about 12 per cent. of fat; if only three hours, the upper third will contain about 8 per cent. of fat. In this top milk when removed the sugar may be regarded as amounting to 4 per cent., and the proteids to very nearly the same.

Chapin recommends that top milk, obtained from milk as ordinarily delivered in quart bottles, be employed, and gives the following assays of various amounts of top milk taken in this way after standing twelve hours:

	Per cent.	Per cent.	Per cent.
Fat in whole milk	3.1	4.3	5.0
Fat in the top 6 ounces	13.4	19.0	23.0
Fat in the top 9 ounces	9.2	12.4	14.6
Fat in the top 12 ounces	7.0	9.6	11.1
Fat in the top 16 ounces	5.8	7.9	9.0

One may in this way obtain a superfatted milk which on dilution will give us the desired percentages of both proteids and fats. Thus if we take a 12 per cent. cream and add to it three parts of water, we shall obtain a milk containing 3 per cent. fat, 1 per cent. proteids, and 1 per cent. milk-sugar. If to each twenty ounces we add one ounce of sugar of milk, we shall then have a milk formula: fat, 3; sugar, 6; proteids, 1—a formula which will agree with most vigorous infants between the second and third months of life. By the use of creams of different strength one may modify the percentage of any of the ingredients and obtain milk of almost any desired strength.

To prevent any impurity arising from the sugar of milk, it is generally deemed advisable that it should be previously dissolved in boiling water and afterward filtered through absorbent cotton. The following table shows the amounts of milk-sugar and water required to make solutions of various strengths:

1 oz. milk-sugar added to	25	oz. water represents	4	per cent.
1 " " " "	20	" " "	5	"
1 " " " "	16⅔	" " "	6	"
1 " " " "	14	" " "	7	"
1 " " " "	12½	" " "	8	"
1 " " " "	10	" " "	10	"

Baner has prepared a series of simple formulæ for determining the amount of cream, milk, water, and milk sugar required to make any desired quantity of modified milk containing certain given percentages. His formulæ are based on the understanding that good average milk contains fat 4, sugar 4, and proteids 4, and that cream is simply a superfatted milk containing practically the same amount of proteids as milk itself. In the formulæ given:

Q represents the total quantity desired in ounces;
F, the desired percentage of fat;
S, the desired percentage of sugar; and
P, the desired percentage of proteids.

To find in ounces the required amount of:

$$\text{Cream} = \frac{Q}{12} \times (F - P);$$

$$\text{Milk} = \frac{Q \times P}{4} - C;$$

$$\text{Water} = Q - (C + M);$$

$$\text{Milk-sugar} = \frac{(S - P) \times Q}{100}.$$

The above formulæ are calculated for use with a 16-per-cent. cream. If 20-per-cent. centrifugal cream is used, the denominator of the cream formula will be 16 instead of 12, and if a 12-per-cent. cream is used it will be 8 instead of 12. It must, of course, be remembered that a milk with a very high fat and a very low proteid percentage cannot be made from cream with only a moderate percentage of fat. From a 16-per-cent. cream it is possible to make the fat percentage only four times the proteid, and with a 12-per-cent. three times the proteid. The great advantage of these equations is their simplicity and the ease with which odd amounts of milk mixtures can be calculated.

Sterilization.—In the infant the digestion of milk is for the most part accomplished in the small intestine. There is no long delay in the stomach with prolonged exposure to an acid and therefore antiseptic medium, as in the adult, but the milk after an imperfect curdling is quickly passed on to the duodenum. Gastric digestion, the safeguard in older children and in adults against the entrance of disturbing micro-organisms into the alimentary tract, affords in infants but a feeble barrier. For this reason one of the more important conditions in the infant's food is that it be sterile. This is the more necessary should the infant's food involve a longer time in its digestion than breast milk.

It is, therefore, extremely desirable that the milk employed in infant feeding be obtained with such careful precautions as to render it practically free from extraneous bacteria. It is not always our good fortune, however, to be able to obtain such with the regularity necessary for the daily preparation of an infant's food, and when our supply cannot be depended upon it appears the lesser of two evils to have the milk pasteurized at the lowest efficient temperature—that is, 60°–68° C. (140°–155° F.). Milk sterilized at over 70° C. is altered to an extent varying according to the elevation of the temperature employed and the duration of the exposure in the following respects: (1st) its proteids are modified and rendered less digestible; our knowledge on this subject, however, is still indefinite and dependent chiefly on clinical experience; (2d) the combination of its saline ingredients with the proteids is to some extent broken up and the salts assume a condition in which they are less readily absorbed; (3d) natural ferments, whose presence in milk may with much probability be inferred and which may materially assist its digestion in the infant's stomach, are destroyed; and (4th) an alteration takes place in the emulsion normal to milk, which may also have distinct effect in lessening its digestibility by the infant. For these reasons, it is important that the milk for infant feeding should not be sterilized at too high a temperature. After pasteurization it should be kept at a continuously low temperature; and it is to be remembered that the employment of sterilized milk which has been kept for many days is not free from danger.

Gärtner's Fettmilch.—In Germany during the last few years a modification of cows' milk has been prepared by Gärtner, as follows: Into the drum of a large centrifuge a mixture of milk and sterile water, at a temperature of from 10°–15° C., is allowed to run, care being taken that the milk used is obtained in the most cleanly manner from healthy cows properly fed. The drum of the centrifuge is made to revolve rapidly, driving the fat, as it is only in suspension, toward the centre of the drum, while the sugar, casein, and salts, which are in solution, remain uniformly distributed. Two tubes which carry off the milk enter the drum, one near the centre and one at the periphery. By arranging how near to the centre the inner tube opens, and the speed at which the drum revolves, milk containing fat in various percentages may be drawn off. As ordinarily set the milk drawn off near the centre has the same amount of fat as mother's milk, and is only deficient in sugar. Its composition, which is fairly constant, is fat 3, sugar 2.5, proteids 1.76. By adding a certain proportion of milk-sugar, milk closely resembling breast milk in composition is obtained.

This plan has also the advantage that any dirt present in milk and most of the bacteria are thrown off toward the periphery, thus leaving the central portion free. It is also claimed that the cream is not so completely separated from the milk as in Rotch's plan, but remains in a more perfect emulsion. Thus prepared the Fettmilch resembles ordinary milk in appearance and has an agreeable taste. Before using it as an infant's food it is recommended that it should be sterilized. Escherich has laid down the following rules for the amount and frequency with which this food may be given:

During each 24 hours children of 2 weeks require 16 ounces in 9 meals; from 2 to 4 weeks, 25 ounces in 8 meals; from 4 to 8 weeks, 33 ounces in 8 meals; from 3 to 4 months, 42 ounces in 8 meals; from 5 to 6 months, 50 ounces in 7 meals.

The employment of this milk is strongly recommended by many eminent German authorities.

Condensed Milk.—When pure fresh milk cannot be obtained, several writers have recommended the use of condensed milk. In the form of fresh evaporated milk (milk condensed without the addition of cane sugar), it may be of much service when pure fresh milk is impossible to obtain. The heat employed during the earlier stages of its preparation has rendered it sterile, and it will therefore keep well for a few days. For ordinary use it should be diluted with from seven to ten parts of water, and fresh cream, if this is obtainable, and sugar of milk added. Keating advised the following as making a useful preparation closely resembling breast milk: Preserved milk, 1 ounce; boiled water, 8 ounces; fresh cream, 1 ounce; sugar of milk, 3 drachms.

The ordinary canned condensed milk has the disadvantage of containing a large amount of cane sugar and a very small amount of fat. When diluted with six parts of water the resulting product on analysis yields fat 1, proteids 1.2, and sugar 8, the latter being chiefly cane sugar. This dilution is generally too strong for the majority of infants, and produces colic and indigestion. When diluted with twelve parts of water, its composition is fat 0.05, proteids 0.06, and sugar 4—a fluid altogether too weak to be efficient as a permanent diet. Holt states that he has not yet seen an infant who was reared exclusively on condensed milk which did not show on careful examination more or less evidence of rickets. During the summer season its use may be permissible for those who are unable to obtain fresh milk. In these cases Kerley advises that a weak meat broth or an albumin water be used as a diluent instead of boiled water, thus increasing the amount of the proteid and rendering it more valuable as a food. The deficiency in the fat may in many cases be supplemented by an emulsion of cod-liver oil.

Patented Food.—When for any reason failure has attended the attempt to feed an infant on cows' milk more or less modified, there is with many parents a strong inclination to resort to one of the numerous patent artificial foods placed before the public by interested agents who loudly vaunt their own special preparations as the exact analogue of mother's milk and the only food calculated to help the infant in its dire distress. We cannot deny that many of these foods have met with much popular favor and that some of them have proved of occasional service. It seems desirable, therefore, that the physician should have a knowledge of their physical properties and their composition further than the meagre and often incorrect statements contained in their advertisements. In almost all these foods dependence is put, for the greater part of the nourishment supplied, on milk which is either added by the user or previously introduced by the manufacturer. They are therefore to be regarded as modifications of cows' milk; a fact which may explain the apparently successful results which sometimes attend their employment.

With the exception of those which contain the milk in a condensed form, all, if administered alone, show a great deficiency in many of the most important ingredients of an infant food, and especially in the element of fat. It is to be noted also that they are secret preparations, over which we as physicians can exercise no supervision or control in regard to the quality of the material or to the amount of care used in their manufacture; that analyses made by many able chemists have given very variable results, often differing widely from the manufacturer's published composition; that they are liable to be old and musty; and that for the poorer classes they are an expensive food. To the analyses of Dr. Leeds we are principally indebted for a knowledge of their more exact composition. He grouped them into three classes. The first class contains the farinaceous foods prepared from the flour of one or more of the cereals, with the starch to some extent modified by baking. All of them, therefore, add a large proportion of starch to the milk dilution, and for this reason are not suitable for infants under six months. They are all liable to deterioration through long keeping. Among the best known of this class are the following: Imperial Granum, Blair's Wheat, Hubbell's Wheat, Hard's Food, Ridge's Food, and Robinson's Patent Barley.

In a second class are placed all those in which the starch is almost entirely converted into a mixture of dextrin, dextrose, and maltose, with a small amount of cane sugar. These foods have in some instances a distinctly laxative action, and may sometimes be of service when the infant is of a constipated habit. The principal foods of this class are Mellin's, Horlick's, and Malted Milk.

A third class comprises those foods to which the milk has already been added during the process of manufacture. All of them contain starch in considerable quantities, to a small extent only converted into dextrose. Their mode of preparation insures more or less complete sterilization of the milk, an important advantage during the summer season. Nestlé's Food, American Swiss, and Gerber's are examples of this class.

An additional class may be made of miscellaneous foods recently introduced, which do not conveniently fall under any one of these divisions, but which may be regarded as to some extent a combination of them. Carnrick's Soluble Food and Allen & Hanbury's Infant Food are examples of this class.

The following table of analyses, copied from Holt, represents the composition of several of these foods when prepared as directed for the infant's use:

INFANT FOODS DILUTED WITH WATER TO COMPARE WITH MILK.

	Breast milk. Per cent.	Condensed milk diluted 6 times. Per cent.	Mellin's food. Per cent.	Malted milk. Per cent.	Nestlé's food. Per cent.	Ridge's food. Per cent.	Imperial Granum. Per cent.	Carnrick's soluble food. Per cent.
Fat	4.00	0.99	0.04	0.39	0.76	0.16	0.14	1.12
Proteids	1.50	1.20	1.50	2.28	1.54	1.67	1.98	1.35
Soluble carbohydrates (sugar)	7.00	7.23	11.56	10.18	6.38	.41	.25	4.06
Insoluble carbohydrates (starch)	.....	......	.....	.....	4.19	10.91	10.65	5.61
Inorganic salts	.20	.17	.45	.50	.24	.07	.06	.56
Water	87.30	90.41	86.45	86.65	86.89	86.78	86.92	87.30

Amount to be Given.—Not only is the character and composition of the food itself of importance, but the amount to be given and the times of giving it demand the physician's careful attention. As Biedert remarks: the infant has no instinct which guards against over-feeding. Even breast-fed children are apt to drink too much, but those artificially fed have a greater tendency to excess, since in general they obtain their food more quickly and with less exertion on their part. The truth should be carefully impressed upon mother and nurse, that a bottle-fed infant thrives best upon the minimum amount of food necessary for good development; excess tends to interfere with digestion, and thus unfavorably affects nutrition.

Dr. Rotch quotes the results of Smitkin's investigations at the Children's Hospital in St. Petersburg, to determine the amount that should be given during the first few weeks of life. He finds that the greater the weight the greater is the gastric capacity, and says that one-one-hundredth of the initial weight of the infant should be taken as the starting figure for each meal, and to this should be added 1 gm. for each day of life.

Illustrations of above rule to serve as guides for especially difficult cases.

Initial weight.	Each feeding.		
	Early days.	At 15 days.	At 30 days.
3,000 gm	30 gm. = (about ℥ i.).	30 + 15 = 45 gm. (about ℥ iss.).	30 + 30 = 60 gm. (about ℥ ij.).
4,500 gm	45 gm. = (about ℥ iss.).	45 + 15 = 60 gm. (about ℥ ij.).	45 + 30 = 75 gm. (about ℥ iiss.).
6,000 gm	60 gm. = (about ℥ ij.).	60 + 15 = 75 gm. (about ℥ iiss.).	60 + 30 = 90 gm. (about ℥ iij.).

The following table (from Rotch) will afford an indication, for an average infant, of the amount to be given at each feeding and the number of feedings which should take place in the twenty-four hours:

GENERAL RULES FOR FEEDING DURING THE FIRST YEAR. (Rotch.)
(The Day feedings are supposed to begin at 6 A.M. and to end at 10 P.M.)

Age.	Intervals in hours.	Number of feedings in in 24 hours.	Number of night feedings.	Amount at each feeding. Ounces.	Total amount in 24 hours. Ounces.
One week	2	10	1	1	10
Two weeks	2	10	1	1½	15
Four weeks	2	9	1	2½	22½
Six weeks	2½	8	1	3	24
Eight weeks	2½	8	1	3¼	26
Three months	2½	7	0	4	28
Four months	2½	7	0	4½	31½
Five months	3	6	0	5½	33
Six months	3	6	0	5¾	34½
Seven months	3	6	0	6¼	37½
Eight months	3	6	0	7	42
Nine months	3	6	0	7	42
Ten months	3	5	0	8½	42½
Eleven months	3	5	0	8¾	43¾
Twelve months	3	5	0	9	45

Very rarely, in the cases of immature and very sickly babies and of infants with cleft palate, the ordinary feeding-bottle is ineffectual, owing to the infants not having power to suck. Feeding by spoon is slow and wearisome to the infant. In these cases Dr. Jacobi recommends the use of Soltmann's *biberon pompe.* In this feeding-bottle simple pressure on the mouthpiece, either by the lips or gums of the infant, or on the expanded portion of the tube outside the bottle by the fingers of the nurse, will cause the food to escape from the bottle. Dr. Jacobi says that in many cases it has done good service. Dr. Rotch recommends the use of a glass cylinder, graduated and capable of holding nine drachms. One end gradually tapers till a small nipple can be fitted on to it; the upper end is covered by a compressible rubber bulb. By gentle compression of this bulb the food may be slowly forced into the infant's throat without any effort on its part.

This method appears to be specially desirable in the case of a weak infant, as it involves no loss of strength.

Gavage.—Some years ago Dr. Tarnier, of Paris, advocated the method of gavage in infants prematurely born or in such as are congenitally weak. The apparatus necessary for the purpose is very simple: a soft-rubber catheter, No. 14 or 15 French, or a piece of gutta-percha tubing with a small glass receptacle, of sufficient size to hold the amount of milk to be administered, attached to the distal end. The child is placed on the knee of the nurse with its head slightly raised. The tube is moistened with milk and introduced at the base of the tongue and then very gently forced down the œsophagus to a distance of 15 cm. The sound is then pinched between the two fingers and the food is introduced into the receptacle. On relaxing the fingers and raising the receptacle the food flows gently into the stomach. Care must be taken to remove the tube gently and quickly; the infant must then be replaced in its warm cradle or couveuse. To the weakest infants 8 gm. of food are given every hour. In spite of this feeding the infant frequently loses weight for the first few days, but soon begins to gain steadily. Dr. Tarnier claims to have achieved marvellous results by this method.

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INFARCTION.—(*Infarcio*, to fill in, to stuff into.) The act of plugging up or filling up; also the organ or tissue which is filled with blood, fluid, or other substances. The development of the various meanings of infarction forms a very interesting chapter in the history of medical terminology. Originally used as a designation for the Galenic teaching of the black bile as the cause of melancholia and hypochondria, *infarctus* gradually came to mean a stoppage of the intestinal canal either through hardened fæcal matter or through precipitations from the blood into the intestinal canal. Later, the idea included also obstruction in the blood and lymph vessels and the ducts of glands. The theory of intestinal infarctus as the cause of hypochondria, melancholia, hemorrhoids, and other conditions reached the height of its development in the latter half of the eighteenth century under the influence of the two Kämpfs, father and son. By them the doctrine was reduced to what was considered to be a scientific basis, the infarcts were obtained for examination by means of injections, and were classified according to symptoms, location, and composition. Their treatment by clysters attained an extraordinary degree of popularity. The abuse of this treatment and the advancement of knowledge of the anatomy and physiology of the gastro-intestinal tract brought about the natural death of the doctrine during the early part of the last century. As outgrowths from the early idea of infarctus were such usages as the following: *infarction of humors*, a term formerly applied to ulcers whose base and borders were infiltrated; *infarctus mammæ lacteus*, the collection of coagulated milk in the ducts of the mammary gland; *infarctus lactei extremitatum*, applied to phlegmasia dolens because it was supposed to be caused by metastasis of the milk to the legs; *infarctus uteri*, applied to a variety of diseased conditions of this organ; etc. The term infarction was also formerly used clinically to indicate a sense of fulness or oppression in the chest. The enlarged spleen in chronic malaria was called *infarctus lienis*. The old meaning of intestinal obstruction still survives in the expression *infarcted hernia*.

At present infarction is unfortunately used as a designation for two classes of pathological conditions essentially different in kind: 1. The infiltration of the tubules or tissue spaces of an organ with blood, blood pigment, uric acid or urates, calcium salts, etc. 2. The anæmic necrosis of an organ or tissue due to an obstruction of its nutrient artery by embolism or thrombosis. The different processes are usually distinguished by some modifying term, as uric-acid infarction, anæmic or hemorrhagic infarction, etc.; but when used without such the term is usually narrowed to the second meaning.

1. Uric-acid Infarction.—In the kidneys of the new-born there is almost always present in the medullary pyramids a number of glistening, golden, or orange-red lines converging to the papillæ. These lines are easily scraped away with the knife and form a glistening orange powder on the moist surface of the organ. On microscopical examination the straight tubules are found to be filled with dark semitranslucent masses which dissolve on treatment with acetic acid, leaving behind an albuminous stroma. From the solution uric-acid crystals are formed. The epithelium of the tubules shows little or no change. The condition is known as the uric-acid infarct of the new-born, and was at one time supposed to be of medico-legal value as occurring only in infants who have breathed; but similar infarcts have been found in the kidneys of still-born children and in the fœtus. In one case of ectopic gestation seen by the writer the kidneys presented an extensive degree of this condition. According to Spiegelberg, uric-acid infarct is present in only one-half of the children examined, being most marked after the second or third day after birth. The condition may persist until the seventy-sixth day, but usually disappears early. When persistent, it may give rise to nephritis or cause uræmia by the simple obstruction of the tubules. Neither the origin nor the significance of the condition is known. The change of metabolism following the establishment of pulmonary oxygenation, the slight degree of oxidation processes in the new-born, lack of ability on the part of the urine to dissolve the uric acid, are among the causes adduced in explanation, but no one of these is adequately supported. Uric-acid and sodium-urate infarcts occur also in the adult kidney in cases of gout or the so-called uric-acid diathesis. The appearances are similar to those in the new-born, but the condition is rarely so extensive. More frequently, scattered concretions are formed in dilated tubules.

Calcium Infarcts, Chalk Infarcts.—In senile kidneys, in osteomalacia and other destructive diseases of bone, in cases of poisoning with mercuric chloride, phosphorus, aloin, bismuth, etc., extensive deposits of lime salts, phosphates or carbonates, may occur in the tubules, the deposit taking place either in or upon the necrotic epithelium of the tubules. When visible to the naked eye, such deposits appear as opaque whitish or yellow streaks corresponding to the tubules, or as minute dots representing the glomeruli. Microsopically the deposits give the specific staining reaction with hæmatoxylin. Calcium-oxalate infarction occurs rarely as the result of ingestion of food containing large amounts of oxalic acid or in cases of disturbed metabolism. White streaks occur in the pyramids similar to those of phosphate infarction, but are distinguished from the latter by their insolubility in dilute acids.

Bilirubin Infarct.—In cases of chronic obstructive jaundice the collecting tubules of the kidney usually contain large numbers of bile-pigment casts. In tissue fixed with alcohol these appear as yellow or brown streaks in the cut surface of the medullary pyramids; in mercuric chloride fixation they have a bright green color. Uric-acid infarction is not infrequently combined with this condition, particularly in cases of icterus neonatorum.

Hæmatoidin Infarct.—In cases of hæmoglobinuria, hæmoglobinæmia, and methæmoglobinæmia, due to poisoning, infections, extensive burns, etc., large quantities of blood pigment may be found in the kidney tubules in the form of brownish casts or irregular masses. The pyramids show radiating yellow or reddish-brown striæ. Usually the pigment does not give the iron reaction, and is therefore to be classed with the hæmatoidin group. Very rarely hæmosiderin infarction occurs.

Melanin Infarct.—Very rarely in cases of extensive metastasis of melanotic sarcomata large quantities of melanin are said to be excreted through the kidneys. In such cases melanin casts are found in the tubules. It is doubtful, however, if the brownish casts described as occurring in these cases were composed of melanin; it is more likely that they were formed of blood pigment.

2. Anæmic and Hemorrhagic Infarction.—The occlusion of a terminal artery by embolism or thrombosis leads to an anæmic necrosis of the part supplied by the

obstructed vessel. In the case of end-arteries having very slight collateral anastomosis the dead area remains anæmic (anæmic or white infarct); in situations where the end-arteries possess sufficient anastomosis to admit of the flow of blood into the affected area from the neighboring terminals the dead area becomes hemorrhagic (hemorrhagic or red infarct). The anæmic variety is found in the spleen, kidneys, heart, brain, retina, and rarely in the liver; the hemorrhagic infarct occurs only in the lungs and the area supplied by the superior mesenteric artery, very rarely in the uterus. Hemorrhagic infarction of the suprarenal has recently been reported.

Infarcts are usually found at the periphery of organs where they form cone- or wedge-shaped areas, the base toward the surface of the organ, the apex pointing inward. They may be single or multiple. As the result of the occlusion of a number of neighboring arterioles they are occasionally very irregular in outline. When recent, the anæmic infarct is opaque, yellowish-white, slightly elevated, and somewhat firmer than normal tissue. A peripheral red zone is almost always present. Older infarcts are usually depressed and softer; in the case of those of large size there is usually a central softening. If organization of the dead area has begun the consistence may be firm. On microscopical examination the cells of the infarcted area show a simple or coagulation necrosis. In older infarcts liquefaction necrosis may be present. The red peripheral zone is found to be due to a narrow line of hemorrhage and congestion surrounding the dead area and may be explained as being of the nature of a hemorrhagic infarct in the zone of collateral anastomosis with the neighboring end-arteries. In later stages this zone usually becomes the seat of a leucocyte infiltration and fibroblastic proliferation. The hemorrhagic infarcts are deep red in color, occasionally pale in very anæmic individuals. They are usually much firmer than the anæmic variety. As they become older they grow lighter in color, and softer if liquefaction necrosis occurs. If organization takes place without softening the infarcted area becomes lighter and firmer. The contraction of the newly formed connective tissue leads to depressions on the surface of organs in the case of both anæmic and hemorrhagic infarcts. On microscopical examination the hemorrhagic infarct is found to consist of an area of necrotic tissue, the spaces of which are filled with extravasated blood. It is in fact only an anæmic infarct which has become hemorrhagic. The term hemorrhagic infarction is applied also to the occurrence of simple hemorrhage in tissues; in the case of the kidney to the hemorrhage produced by obstruction of the renal veins. It would be better to drop entirely this confusing use of the term and restrict its application to the true anæmic and hemorrhagic-anæmic necroses produced by arterial obstruction.

Various theories have been offered in explanation of the fact that infarcts in one case are anæmic and in another hemorrhagic. It is held by some that the anæmic infarct is but a later stage of the hemorrhagic, produced by the removal of the blood pigment from the latter. Old hemorrhagic infarcts are not infrequently lighter in color for this reason, but the fact remains that anæmic infarcts are non-hemorrhagic from the beginning except for the small peripheral zone of hemorrhagic infarction surrounding them. The true explanation is probably to be found in the character of the collateral anastomosis of the affected vessels, as well as in local and general conditions of the circulation. Where there is rich anastomosis, as in the lung and mesentery, the obstruction of an end-artery leads to a temporary anæmia which lowers the vitality of the tissue supplied by the obstructed vessel; later, an inflow from the collaterals takes place, but the damaged condition of the vessel walls in the anæmic area leads to extravasation, chiefly by diapedesis, but also by rhexis. The infiltration of the tissue spaces thus produced leads to further damage of the part. Very rarely the local or general conditions of blood pressure may be such in organs in which hemorrhagic infarcts are usually produced that but little blood flows into the anæmic area and the resulting infarct is pale in color. The anæmic infarct occurs in organs whose end-arteries have but little anastomosis, so that no inflow takes place into the anæmic area except just at the periphery, where a narrow zone of hemorrhagic infarct is formed. In cases of extreme local or general congestion this peripheral zone of hemorrhage may be greatly broadened, or in the case of small infarcts the entire area may become hemorrhagic. The inflow of blood is usually under such slight pressure that the integrity of the part cannot be maintained.

Under ordinary conditions the infarcts of the brain are always of the anæmic variety, with more or less peripheral hemorrhage. Liquefaction of the affected area takes place, and if death does not result brain cysts may be formed. Occlusion of the coronary arteries by thrombosis, embolism, or sclerotic changes in the vessel walls produces anæmic infarction of the myocardium, attended by more or less hemorrhage. The infarcts of the kidney and spleen are almost always of the anæmic variety with a narrow zone of hemorrhage. True anæmic infarcts of the liver are very rare. In the normal lung the obstruction of a terminal artery will not produce infarction owing to the rich anastomosis. In conditions in which the pulmonary circulation is already embarrassed, as in the passive congestion of mitral disease, embolism or thrombosis of the pulmonary arteries is quickly followed by infarction. This is practically always of the hemorrhagic variety except in very rare cases, due to extreme weakness of the circulation. The conditions in the superior mesenteric artery are similar to those in the lungs, but inasmuch as the anastomosis is not sufficient to re-establish the circulation after occlusion, obstruction of the terminals of this artery leads more quickly to infarction than in the case of the pulmonary arteries. According to Chiari, bilateral embolism of the hypogastric arteries or bilateral thrombosis of the uterine veins is followed by hemorrhagic infarction of the uterus.

The sequelæ of infarction are: absorption of the necrotic tissues, organization, scar formation, calcification, cyst formation, encapsulation, abscess, or gangrene. In cases of infective embolism suppuration of the infarcted area usually occurs (septic infarct), or the infarct may be secondarily infected by pyogenetic organisms. Infarction of the lungs is frequently followed by moist gangrene, infarction of the intestine almost always. (See *Heart*, *Kidneys*, etc.) *Aldred Scott Warthin.*

INFECTION.—Probably one of the most universally known facts respecting bacteria is that they are related to the development of certain pathological processes; but it should be clearly held in mind that many play a very beneficent part in nature, chiefly by decomposing dead organic material and thus forming other chemical compounds which may be utilized for food by other plants and animals. It has been seen, in the article on *Bacteria*, that micro-organisms are widely distributed in air, soil, and water; and it is among the habitations of man, where the conditions for their growth and multiplication are specially suitable, that they are most numerous. So far as we know, with few exceptions micro-organisms whose natural habitat is in the soil, air, or water are not under usual conditions harmful to man, for they are invariably present in greater or less numbers in the mouth, nose, upper respiratory passage, gastro-intestinal tract, and on the surfaces of the skin, where they are more or less constantly brought by the respired air, by food and drink, and in many other ways. Notwithstanding, however, their occurrence in these situations in great numbers, they do not often gain entrance into the body tissues, so that under normal conditions the blood and viscera are germ-free.*

Although the cutaneous and mucous surfaces of the body are covered with many micro-organisms, these are for the most part harmless, sometimes serving useful functions, as do those in the intestines. Whenever they find their way into the body, conditions are so unsuitable for their existence that they are soon destroyed. Against such incursions the body is guarded in various ways. Among the protective agencies may be mentioned the epithelial investments of the skin and mucous membranes, which so long as they are intact protect the interior from bacterial invasion. Moreover, the germicidal qualities of some of the body fluids and cells also afford important protection. But notwithstanding these protective factors bacteria do sometimes enter, and this may especially occur whenever the skin or mucous membranes are injured, even if ever so slightly so.* Within recent years the entrance of bacteria through the bites of insects has been especially studied.†

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* For a consideration of the bacterial flora of the body surfaces consult Welch: "Surgical Bacteriology." "System of Surgery by American Authors," edited by Dennis.

Among those gaining entrance into the body, there are some which may under suitable conditions induce phenomena by which disease is characterized. These are the micro-organisms which induce infectious diseases and which we habitually refer to as being pathogenic bacteria. The term pathogenic is, however, a relative one—a fact which should be clearly held in mind for the following reasons: First, an organism quite harmless to one animal may be capable of inducing disease in another; second, an organism which under ordinary conditions is harmless may under special conditions give rise to serious lesions; third, many organisms generally regarded as harmless under special conditions may prove injurious. Thus it is evident from what has been said that infectious disease cannot exist without the presence in the body of living micro-organisms. But, on the other hand, the mere entrance of bacteria into the tissues is not sufficient to constitute infection, for it has been seen that many bacteria are harmless and that the body possesses important safeguards whereby bacteria are destroyed and disposed of. Whether the micro-organism possess pathogenic activity or not will depend largely upon the host and also upon its own variable nature and qualities.

This relationship of host and bacterial excitant has been so admirably stated by Prudden that one can do no better than quote the following:

"In the study of the infectious diseases it is especially important to bear in mind that the abnormal processes through which the disturbances incited by micro-organisms are manifested are processes of the body cells and not processes of the micro-organisms. The micro-organisms do indeed incite the train of phenomena by which the disease is manifested, and the nature or 'species' of the micro-organism may largely influence the character of the phenomena; but the stored-up energy which is released in this manifestation is body-cell energy and not that of microbic metabolism. The microbes are excitants of disease, but the disease is a performance of the body cells. If these obvious considerations be held in view, it will be convenient in considering certain of the infectious diseases to use the familiar and much-abused term 'specific' as indicative of those phases of abnormal body cell performance which are apt to occur in characteristic ways in response to special forms of microbic stimulus. Thus the poisonous substances which the tubercle bacillus build up out of the organic material upon which it feeds are in part such as exert a peculiar influence upon connective-tissue cells, leading to their proliferation and the temporary formation of new tissue—the tubercle. This, together with associated action of the same or other metabolic products of the living bacillus, forms a group of lesions and disturbances which is characteristic of the action of the tubercle bacillus in the body. In this sense tuberculosis is a 'specific' disease. On the other hand, the poisons eliminated by the tubercle bacillus may incite responses on the part of the body cells which are practically identical with those which many other toxic substances, both of bacterial and of other origin, induce—fever, degeneration, etc. These manifestations of the action of the tubercle bacillus upon the living body cells are not 'specific.'"

The Bacterial Excitant.—The reaction of the body cells in infection bears a more or less constant relation to the virulence of the infecting micro-organism and to the number of bacteria gaining entrance into the tissues. The virulence varies considerably under different conditions, and according as these variations are small or great different phenomena will develop within the body. The character of the processes induced will necessarily vary according to the virulence of the infecting bacterium; and this largely depends upon its environment, which may not only modify its morphological characters, but also may change its physiological activities. For example, the Bacillus coli communis as normally found in the intestines is of very low virulence and is not capable of inciting pathological processes, but so soon as its physiological activities are modified by changes in its environment, its virulence is apt to be very much increased. This influence of environment is also well shown by the modifications which may occur in the vital activity of an organism when it finds its habitat in new and unnatural hosts. This point is especially well demonstrated with the mammalian tubercle bacillus, which when transmitted for a long time through another animal host, as birds, will ultimately lose its virulence for the host from which it was originally derived.

As a rule, bacteria lose their virulence with greater or less readiness when cultivated in artificial media. On the other hand, successive passages of a pathogenic organism through susceptible animals exalt its virulence. Thus a streptococcus of attenuated virulence may be exalted a hundredfold by successive inoculations into rabbits.

Differences in the virulence of bacteria often suffice to explain differences in the clinical and morphological types of disease. It is well known that under some conditions an organism of low virulence will incite rather mild reactions of the body cells, whereas under other conditions, when the virulence of the same organism is exalted, the effects are both more marked in severity and in extent of the lesions. Thus I have been able to follow these variations in virulence in the different forms of tuberculosis. For example, in scrofulous lymphadenitis, I have found that the tubercle bacilli which induce this lesion were usually of low virulence, whereas the tubercle bacilli inducing acute miliary tuberculosis are on the other hand of extraordinary pathogenic activity.

The number of micro-organisms which gain entrance into the body is also a factor which modifies the character and extent of the cellular reactions. Within certain limitations the healthy body may dispose without apparent injury of a certain number of given virulence, but when the same organism is introduced in large quantities infection follows. In susceptible animals probably so small a number as one or two anthrax bacilli may incite disease. Usually, however, much larger numbers are necessary for the development of an infection. Further, according to the portal of entry, the number may be increased or diminished. Thus a given dose of bacteria, which when injected into the subcutaneous tissues of an animal may prove quite harmless, will incite, when the same dose is introduced intravenously or into the peritoneal cavity, well-marked disease to follow.

The Host.—This is a factor of the very greatest importance in the consideration of infection in its numerous aspects. It is, of course, well known that certain bacteria will induce infections only in certain species of animals, proving absolutely innocuous for other species. Thus, while the anthrax bacillus usually induces lesions with the greatest readiness in many animals, others, like the white rat, are ordinarily insusceptible to inoculation with these bacilli, unless very large amounts are given or special factors be brought into play. Some diseases are especially peculiar to man, such as typhoid fever, syphilis, leprosy, scarlet fever, measles, etc., these diseases never occurring naturally in other animals. The race and individual peculiarities are also factors which modify the liability to infection. Thus negroes are generally insusceptible to yellow fever, whereas other human beings are quite susceptible to the pathogenic agent of this disease. The influence of age is so well known that investigators commonly make use of this knowledge in their experimental work. It may be stated as a rule that young animals are much more readily infected than older and larger ones. Age as a predisposing factor to infection is well illustrated by the curve of frequency of infectious diseases in man, the maximum point occurring among children. Sex is also sometimes a factor predisposing to infectious disease, although this is not so apparent among animals as it is among human beings. Numerous other conditions affecting the physiological integrity of the body are also predisposing influences for infection. The influence of fatigue, starvation, cold and heat, and loss of blood have been particularly studied from the experimental point of view, the results very conclusively proving that a marked susceptibility to infection is developed.

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* The view has been recently advanced that with no apparent lesion of the intestinal mucosa, bacteria in large numbers may gain access through this to the liver under what seems to be perfectly normal conditions (Adami: Jour. of the American Medical Association, December 16th and 23d, 1899).

† For a consideration of the rôle of insects in the transmission of disease consult Nuttall: Johns Hopkins Hospital Report, 1900, vol. viii.

Animals which are normally insusceptible to anthrax, such as white rats, may be made vulnerable by fatigue. Thus Charrin and Roger have shown that if white rats be made to work a treadmill until thoroughly fatigued, and be then inoculated with anthrax bacilli, they succumb to the lesions of anthrax infection.

Canalis and Morpurgo have shown that starvation also interferes with the natural resistance of animals to bacterial infection. These observers studied this phase of the subject with pigeons, which are also naturally resistant against anthrax. By starving these animals, either before or just following inoculation, they are made extremely susceptible to the influence of the inoculated organism. These experiments have been repeated time and again with other animals, especially by Pernice and Alessi.

The influence of exposure to heat, cold, and moisture has been similarly investigated by Pasteur, Petruschky, and others. Long ago Pasteur showed that by immersing a hen in cold water it loses its natural immunity to anthrax. Frogs, if kept at a temperature (25°–35° C.) higher than is normal for them, will easily succumb to anthrax infection; and guinea-pigs and white mice, which are resistant to fowl tuberculosis, can be made susceptible by keeping them after inoculation in a warm chamber at 43°–45° C.

Any injury to the body tissues also favors the lodgment and activity of whatever bacteria may reach the affected area. It is a well-known clinical fact that tuberculosis of bones and joints of children often follows different forms of trauma. Rosenbach demonstrated this predisposition of damaged tissues to bacterial invasion by traumatizing one of the heart valves and then injecting cultures of the staphylococcus. Malignant endocarditis almost invariably followed, whereas in the control animals in which the valves had not been injured no lesions of endocarditis were found.

Other factors have also been well investigated, such as the action of chemical substances and unsuitable diet, the latter especially by Hankin, who fed refractory rats on sour milk and bread. Such treatment made the animals extemely susceptible to anthrax infection. Leo administered phloridzin in small doses, and reached the conclusion that it markedly predisposed the animals to bacterial infection. There are still other special influences which may more or less modify the conditions in the development of infection. The removal of certain organs, such as the removal of the pancreas from pigeons for example, will make the body tissues more susceptible than they would otherwise be to the infection. Animals kept in dark and damp places also exhibit marked susceptibility as compared with those living in light and airy localities. Trudeau has conclusively established that rabbits kept in places in which no light penetrates contract tuberculosis more readily than others kept in a more healthful environment.

Portals of Entry of Bacteria.—Bacteria may gain entrance into the body tissues through several different ways, and according to the portal of entry differences not only in the susceptibility of the animals but also in the lesions and symptoms of the disease will be noted. For the most part micro-organisms reach the interior of the body from the skin and mucous surfaces. It is very improbable that bacteria present upon the skin can penetrate this tissue when uninjured. It is true, however, that very often they seem to reach the interior of the body from what seems to be an uninjured skin surface, but in these cases it is probable that the skin injury has been overlooked on account of its smallness. Attention has already been called to the fact that bacterial agents may be communicated through the bites of different insects. Thus it is now a well-established fact that the malarial parasite is transmitted through the bite of the mosquito; and the same is probably true for yellow fever. The mucous membranes of the respiratory and alimentary tracts are frequently portals of entry for micro-organisms which have been carried by the air and water and foods. The mucous membrane of the urogenital tract is less frequently a portal of entry. Other mucous surfaces, such as the conjunctiva, may also under special conditions be points of entry for different pathogenic bacteria. It is only very rarely that bacteria directly gain entrance into the general blood current; they ordinarily reach it through the sources which have been mentioned.

Animal experiments clearly show that the portal of entry and channel of infection bear a more or less direct relation to the severity of the infection which follows. Subcutaneous inoculations in animals are usually much less severe in their results than those made directly into the peritoneal cavity or general vascular system.

Action of Bacteria and Their Products in the Body.—Micro-organisms induce their bad effects in several ways, but chiefly by their presence in the tissues and development of their poisonous products, which either affect the physiological activity of the cell or kill the cell outright. These poisonous products act generally or locally in varying degree, according to the nature and quantity of the product formed. These toxic substances become diffused through the system, and their effects are manifested clinically by the occurrence of fever or disturbances in the functions of the respiratory and nervous systems. In some cases changes are found in the local tissues directly involved. The general effects of bacterial poisons may be so slight as to be regarded of little importance, as in the case of a local inflammation, for example; or they may be very intense, as in tetanus and diphtheria. These results are largely directly attributable to the poisons of the bacteria, rather than to the presence of the organisms themselves. In infectious diseases both factors are prominent features, the toxic side being usually more conspicuous.

In diseases like tetanus and diphtheria it is usually only in the local lesion that the bacilli are found. The profound systemic intoxication is accomplished by absorption of the highly toxic products from the local lesion.

Whenever there is a widespread distribution of pathogenic bacteria in the blood the condition is designated septicæmia; and if associated with multiple foci of pus formation the term pyæmia is applied. The body which is already the seat of infectious disease is much more susceptible to the invasion by other bacteria; thus mixed or concurrent infections are often established, as in tuberculosis of the lungs with cavity formation. In addition to the tubercle bacillus there may usually be found in such lungs pyogenic (pus excitants) bacteria. Individuals the victims of long-standing chronic diseases, such as those of the heart, lungs, kidneys, and liver, often succumb to infectious diseases of one kind or another. The phrase "terminal infection" has been applied by Osler to these infectious diseases.

Communicability of Infectious Disease.—Considered in its practical relations, the subject of the communicability of infectious disease is one of the very highest interest and importance. It has been already pointed out that some infectious diseases, like syphilis, cannot be communicated to animals. On the other hand, some of the infectious diseases of animals are not communicable to man. But certain other infectious diseases, like tuberculosis, are readily transmitted to either man or animals.

The infectious diseases of man may be divided into two great classes: first, those which under usual conditions are communicable; and second, those which under usual conditions are very communicable. Among those of the second class there exist the greatest differences in the liability to transmission. It is well known how readily the excitants of smallpox and scarlatina are given off from the patients under conditions which make their transmission from one person to another an easy matter. In diseases like syphilis and hydrophobia, on the other hand, the excitant is transmitted only by direct inoculation. Between these extremes we have many gradations. It should be clearly borne in mind that a classification based on the communicability of a disease is not fundamental, but is closely dependent upon the sanitary conditions under which these diseases are observed.

Immunity.—Immunity is characterized by resistance to infection or its effects. The absence or loss of this capacity is known as susceptibility. Immunity from an infectious disease may be *hereditary*, or it may be *acquired*, either by an attack of the disease from which the individual has recovered—*natural immunization*—or by the introduction into the body of something which diminishes susceptibility—*artificial immunization*. Acquired immunity may be transmitted from parent to offspring.

Many of the infectious diseases confer greater or lesser immunity to subsequent attacks of the same disease, although there are some exceptions to this. A previous attack of erysipelas makes one more susceptible to subsequent infection with the streptococcus.

From the study of infection it is known that two distinct influences are evidently at play in enabling the body to resist infection. It has been clearly shown that the destruction of bacteria may in part be brought about by the leucocytes and other mesodermal cells, which when thus engaged are called phagocytes. In the body fluids there are also certain albuminous ingredients—alexins or "defensive proteids"—which have well-marked bactericidal properties.

Artificial immunization is generally accomplished by making the body tissues tolerant to the presence of bacteria or their poisons. This may be done by the introduction of attenuated micro-organisms or by the introduction of their poisons. The same result may be obtained by introducing the body fluids from an already immune individual.

This immunizing power is attributable to the development of "antitoxic substances" whose nature is still little understood. They seem to be closely related to the globulins.

It is not possible to determine to what extent the immunization effected is specific. In some cases it seems to be so; whereas in others this is less apparent.

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INFILTRATIONS.—The collection of fluid or cells in the tissue spaces, and the deposit in or between the cells of substances abnormal in kind or quantity, are included in the comprehensive class of *pathological infiltrations*. The processes involved are of widely differing nature; each variety of infiltration being usually indicated by some modifying designation, *hemorrhagic, inflammatory, tuberculous, leukæmic, tissue infiltration*, etc. Without such specific designation infiltration is commonly taken to refer to the presence of some pathological substance in or about the cells, and is used as a synonym for pathological deposit. The infiltrated substance itself is also usually spoken of as an infiltration.

Fluid Infiltrations.—Œdema, non-inflammatory in origin, is sometimes spoken of as a hydropic or dropsical infiltration. As a result of injury to the bladder or urethra extravasation of urine into the surrounding tissues, particularly into the perineum, may occur (urinary infiltration). Extravasations of blood, lymph, milk, fæcal material, etc., are also styled infiltrations.

Inflammatory Infiltration.—This may be hemorrhagic, serous, fibrinous, or cellular in character. The collection of serous exudates in tissue spaces is usually spoken of as inflammatory œdema. Fibrinous infiltrations occur in diphtheritic inflammations and other forms of coagulation necrosis. The cellular infiltration of inflammation is for the chief part composed of leucocytes that have migrated from the blood-vessels. Wandering cells arising from proliferating tissue cells may also be found in it. Usually the leucocytes are of the polynuclear variety, but occasionally the infiltration is made up entirely of mononuclear forms. In some cases the cells of the infiltration are chiefly plasma cells; in other cases eosinophile or mast cells may be very numerous. The significance of these phenomena is as yet unknown. A leucocyte infiltration of moderate degree is usually spoken of as a small-celled infiltration; when the leucocytes are in large numbers as a purulent infiltration. (See *Inflammation* and *Exudations.*)

Leukæmic Infiltration.—An increase in the number of the leucocytes in the blood is attended by an increase in the number of the wandering cells in the tissue spaces. This increase is greatest in such organs as the liver and kidneys, and in the submucosa and mucosa of the gastro-intestinal tract. In leukæmia the accumulation of leucocytes in the interstitial tissue throughout the entire body may reach an enormous degree. The liver and kidneys become enlarged, firmer, and lighter in color as the result of such an infiltration. This may be diffuse, or circumscribed grayish-yellow areas of infiltration may occur throughout the organ (leukæmic nodes, lymphoma). The mucosa of the larynx may be infiltrated to such an extent as to give rise to symptoms of œdema of the glottis. In the intestine the swelling of the mucosa may be followed by ulceration. The variety of leucocyte present in the infiltration depends upon the kind of leukæmia, though in some cases of mononuclear leukæmia the proportion of polynuclear forms in the tissues far exceeds that in the blood. Proliferation of the migrated cells occurs, as shown by the occurrence of cell-division figures.

Tumor Infiltration.—The malignant neoplasms, carcinoma and sarcoma, invade adjacent tissues by extension through the tissue spaces in the direction of least resistance, usually through the lymph spaces. This process is styled growth by infiltration. Extension in this manner is always more marked in the case of carcinoma than in that of sarcoma. Around the infiltrating growth there is almost always present a zone of leucocyte infiltration as evidence of the inflammatory reaction produced by the development of the tumor. In many cases it is very difficult or impossible to distinguish between the leucocytes and the young tumor cells.

Tissue Infiltrations.—The term infiltration is very frequently used as a synonym for both pathological degenerations and deposits (albuminoid, hydropic, fatty, glycogenic, cholesterin, mucous, hyaline, amyloid, calcareous, uratic, and pigmentary infiltrations). Inasmuch as in the majority of these conditions the process is of the nature of a deposit in the affected tissue, the designation of pathological deposit seems preferable to that of infiltration. (See *Degeneration* and *Deposits.*)

Tuberculous Infiltration.—The confluence of small miliary tubercles may give rise to a diffuse tuberculous process, or the epithelioid tissue of tubercles may infiltrate into the neighboring tissues after the manner of a new growth. Both of these conditions are included under the head of tuberculous infiltration. The term gelatinous infiltration was used by Laënnec to designate the grayish-red fibrinous exudate filling up the lung alveoli in the neighborhood of tubercles.

Syphilitic Infiltration.—Circumscribed or diffuse gummatous processes affecting bone were formerly designated as gummatous infiltrations.

Parasitic Infiltration.—The presence of large numbers of bacteria in the tissue spaces, the occurrence of the filaria in the lymph spaces and vessels, the invasion of muscle by trichina, etc., are frequently designated as infiltrations.

Aldred Scott Warthin.

END OF VOLUME IV.